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Cook Mountain Study Area Report

RESOURCE & POTENTIAL RECLAMATION EVALUATION

Cook Mountain Study Area Report
Published March 1983

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Cook Mountain Study Area Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management and Bureau of Reclamation. The study effort began in 1979 and was concluded in 1983 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential, should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

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16. Abstract (Limit: 200 words) The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The study area, located in southeastern Montana, lies within the unglaciated portion of the Great Plains Physiographic Province. The area is generally rolling and has been thoroughly dissected. Climatic conditions are characterized by warm summers, cold winters, and large variations in seasonal precipitation. Average annual precipitation is 13.8 inches; the frost-free season averages about 114 days. Bedrock exposed in the uplands and along deeply-incised drainages is the Tongue River Member of the Paleocene Fort Union Formation. Holocene alluvial deposits mantle drainage bottoms and a large upland terrace in the study area. Two coalbeds, the Knobloch and Sawyer, were penetrated by 24 drill holes in the study area. The Knobloch has a classified rank of subbituminous C; the Sawyer is ranked lignite A. The total estimated original resources in the study area for the two coalbeds combined is 367,170,000 tons. The alluvial/colluvial soils, which occupy about 20 percent of the study area, should yield 12 to 24 inches of easily stripped topsoiling material and 6 or more feet of fair to good quality subsurface material. Though they cover about 80 percent of the study area, the residual soils forming from sandstone or shale represent a limited source of revegetative material due to their shallow nature and the highly dissected uplands they occupy. Thirty-seven soil and overburden samples were stratified in the greenhouse as to their comparative revegetation potential.

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COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD
POWDER RIVER AND ROSEBUD COUNTIES
MONTANA

CONTENTS

Page

Introduction---------- 1
Purpose---------- 1
Report Objectives---------- 1
Authority---------- 2
Responsibility---------- 2
  Bureau of Land Management---------- 2
  Bureau of Reclamation---------- 2
General Description---------- 2
  Location---------- 2
  Present Land Uses---------- 3
  Postmining Land Uses---------- 3
Rules Governing Mining and Reclamation Operations---------- 4
Objective of Reclamation---------- 5
Physical Profile---------- 6
  Climate---------- 6
    Precipitation---------- 6
    Temperature---------- 6
    Effect of Climate on Revegetation---------- 7
  Physiography---------- 8
  Geology---------- 9
    Regional Geology---------- 9
    Area Geology---------- 9
      Investigations---------- 9
      Stratigraphy---------- 10
        Paleocene---------- 10
        Holocene---------- 10
      Clinker---------- 11
      Coalbeds---------- 11

CONTENTS (Cont'd)

Page

Structure---------- 12
Paleontology---------- 12
Engineering Geology---------- 12
Slope Stability---------- 12
Overburden Expansion---------- 13
Instability of the Postmining Landscape---------- 13
Weathering Tests---------- 14
Seismic Hazard---------- 14
Coal Resources---------- 16
Estimation of Coal Resources---------- 16
Coal Analyses---------- 16
Rank and Weight---------- 16
Thickness of Coalbeds---------- 17
Thickness of Overburden---------- 17
Tabulation of Coal Resources---------- 17
Summary of Coal Resources---------- 18
Soil and Overburden---------- 19
Principal Soil Bodies---------- 19
Residual Soils---------- 19
Alluvial/Colluvial Soils---------- 19
Land Suitability Classification---------- 20
Results of Land Suitability Classification---------- 21
Soil and Overburden Suitability for Revegetation---------- 22
Soil Mantle Suitability---------- 22
Overburden Suitability---------- 23
Greenhouse Evaluation of Soil and Overburden Materials---------- 25
Introduction---------- 25
Preplant Analysis of Soil and Overburden---------- 25
Plant Analyses Data---------- 26
Plant Growth Aspects---------- 26
Plant Tissue Analysis---------- 27
Postharvest Analysis of Soil and Overburden---------- 27
Summary of Findings---------- 27

CONTENTS (Cont'd)

Bibliography

Appendix A - English to Metric Conversions

Appendix B - Geology

Appendix C - Coal Resources

Appendix D - Soil and Overburden

Appendix E - Greenhouse

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PLATES

	Follows Page (Number) or located in Appendix (Letter)
Plate 1 - General Location Map	2
Plate 2 - Location and Land Ownership Map	2
Plate 3 - Mineral Status Map	2
Plate 4 - Generalized Regional Geologic Map	10
Plate 5 - Stratigraphic Column	10
Plate 6 - Geologic and Investigations Map	10
Plate 7 - Geologic Section W-X	10
Plate 8 - Geologic Section Y-Z	10
Plates 9-24 - Geologic Logs of Intrasearch Drill Holes 24424-1 through 3458-3C	B
Plate 25 - Overburden Thickness Map - Knobloch Coalbed	12
Plate 26 - Overburden Thickness Map - Sawyer Coalbed	12
Plates 27-29 - Semi-Detailed Land Classification Maps	D
Plates 30-32 - Topsoiling Material Maps	D
Plates 33-35 - Subsurface Material Maps	D

FIGURES

Figures 1 through 8 - Greenhouse Data: Dry Weight of Plants	E

TABLES

	Follows Page (Number) or located in Appendix (Letter)
Table 1A - Potential Consumptive Use of Moisture and Available Moisture-Native Grasses	8
Table 1 - Elevation Changes Due to Bulking	14
Table 2 - Summary of Coal Analyses - Knobloch Coalbed	16
Table 3 - Summary of Coal Analyses - Sawyer Coalbed	16
Tables 4-11 - Coal Reserves, Overburden and Interburden Volumes and Ratios, Acres and Tons per Acre of Knobloch Coalbed:	
4 Within T. 2 S., R. 44 E., Section 14	C
5 Within T. 2 S., R. 45 E., Section 18	C
6 Within T. 2 S., R. 45 E., Section 29 (S1/2)	C
7 Within T. 2 S., R. 45 E., Section 30	C
8 Within T. 2 S., R. 45 E., Section 32	C
9 Within T. 3 S., R. 45 E., Section 4 (W1/2)	C
10 Within T. 3 S., R. 45 E., Section 6	C
11 Within T. 3 S., R. 45 E., Section 8	C
Tables 12-19 - Coal Resources, Overburden and Interburden Volumes and Ratios, Acres and Tons per Acre of Sawyer Coalbed:	
12 Within T. 2 S., R. 44 E., Section 24	C
13 Within T. 2 S., R. 45 E., Section 18	C
14 Within T. 2 S., R. 45 E., Section 29 (S1/2)	C
15 Within T. 2 S., R. 45 E., Section 30	C
16 Within T. 2 S., R. 45 E., Section 32	C
17 Within T. 3 S., R. 45 E., Section 4 (W1/2)	C
18 Within T. 3 S., R. 45 E., Section 6	C
19 Within T. 3 S., R. 45 E., Section 8	C

TABLES

	Follows Page (Number) or located in Appendix (Letter)
Table 20 - Measured, Indicated and Inferred Coal Reserves of the Knobloch Coalbed	18
Table 21 - Measured, Indicated and Inferred Coal Reserves of the Sawyer Coalbed	18
Table 22 - Weighted Average Overburden and Interburden Stripping Ratio of the Knobloch Coalbed	18
Table 23 - Weighted Average Overburden Stripping Ratio of the Sawyer Coalbed	18
Table 24 - Point Site Soil Profile - Residual Soil Overlying Sandstone	D
Table 25 - Point Site Soil Profile - Residual Soil Overlying Shale	D
Table 26 - Point Site Soil Profile - Alluvial/Colluvial Soil (Low Terrace)	D
Table 27 - Point Site Soil Profile - Alluvial/Colluvial Soil (Bottomland)	D
Table 28 - Point Site Soil Profile - Alluvial/Colluvial Soil (Low Terrace)	D
Table 29 - Point Site Soil Profile - Alluvial/Colluvial Soil (Upland Terrace)	D
Table 30 - Point Site Soil Profile - Alluvial/Colluvial Soil (Footslope)	D
Table 31 - Land Suitability Specifications	20
Table 32 - Description of Land Classes	22
Table 33 - Results of Land Suitability Classification	22
Table 34 - Laboratory Data - Intrasearch, Inc., Drill Hole 24530-2C	D
Table 35 - Laboratory Data - Intrasearch, Inc., Drill Hole 3458-3C	D
Table 36 - Results of Trace Element Analyses on Samples from USBR Point Site Soil Profiles	D
Table 37 - Criteria Used to Determine Suitability of Overburden Material for Use as Plant Media in Revegetation	D
Table 38 - Suitability of Overburden Material for Use as Plant Media in Revegetation	D

TABLES (Cont'd)

	Follows Page (Number) or located in Appendix (Letter)
Table 39 - Preplant Analysis of Soil and Overburden Material - Greenhouse	26
Table 40 - Plant Yield Data - Greenhouse	26
Table 41 - Analysis of Variance of Fresh and Dry Weights as Related to Soils	E
Table 42 - Test of Significance of Means of Dry Weight versus Soil Horizons	E
Table 43 - Test of Significance of Fresh Weight versus Soil Horizons	E
Table 44 - Descriptive Condition of Plants on August 13, 1981	E
Table 45 - Top/Root Ratio for Selected Soils	E
Table 46 - Correlation Coefficients for Preplant Analysis	E
Table 47 - Plant Tissue Analysis	E
Table 48 - Comparisons of Plant Tissue Analysis with Other Data	E
Table 49 - Correlation Coefficients for Plant Tissue Analysis	E
Table 50 - Postharvest Available Soil Analysis	28
Table 51 - Postharvest Total Soil Analysis	28
Table 52 - Postharvest Available versus Dry Weight Correlation Coefficients	28
Table 53 - Postharvest Total versus Dry Weight Correlation Coefficients	28

EXHIBITS

Exhibit 1 - Screenable Soil Characterization as Related to Land Reclamation	D
Exhibit 2 - Soils and Water Laboratory Procedures and References	D
Exhibit 3 - Glossary	D

RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF COOK MOUNTAIN STUDY AREA ASHLAND COALFIELD POWDER RIVER AND ROSEBUD COUNTIES MONTANA

INTRODUCTION

Recent energy shortages have drawn attention to the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. As a result, numerous investigations by the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program have been undertaken by the U.S. Department of the Interior in order to quantify those coal resources, and at the same time, to provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide baseline resource information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, engineering geology, coal resources, coal quality, soil and overburden, and greenhouse investigations. Less detailed information is provided on climate and physiography.

REPORT OBJECTIVES

1. To analyze and quantify the environmental impacts from surface mining of coal.

2. To provide resource and impact information for leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support State and local regional development and land use planning efforts.

5. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation over known coal deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

RESPONSIBILITY

BUREAU OF LAND MANAGEMENT

1. Selects study area for coordinated investigations of climate, geology, soils, overburden, and coal resources.

2. Acts as Contracting Officer in the coordination, establishment and execution of work orders.

3. Procures easements and rights-of-way to conduct the studies.

4. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

5. Determines postmining land uses.

BUREAU OF RECLAMATION

1. Conducts a land classification for determining suitability of soil/overburden material within 10 feet of the surface for use in revegetation of the disturbed area.

2. Maps and records geology.

3. Arranges for greenhouse investigations to determine comparative revegetation potential of predominant soil materials within the study area.

4. Reviews existing resource data and incorporates pertinent parts into the final report.

5. Coordinates assembly and printing of final report.

GENERAL DESCRIPTION

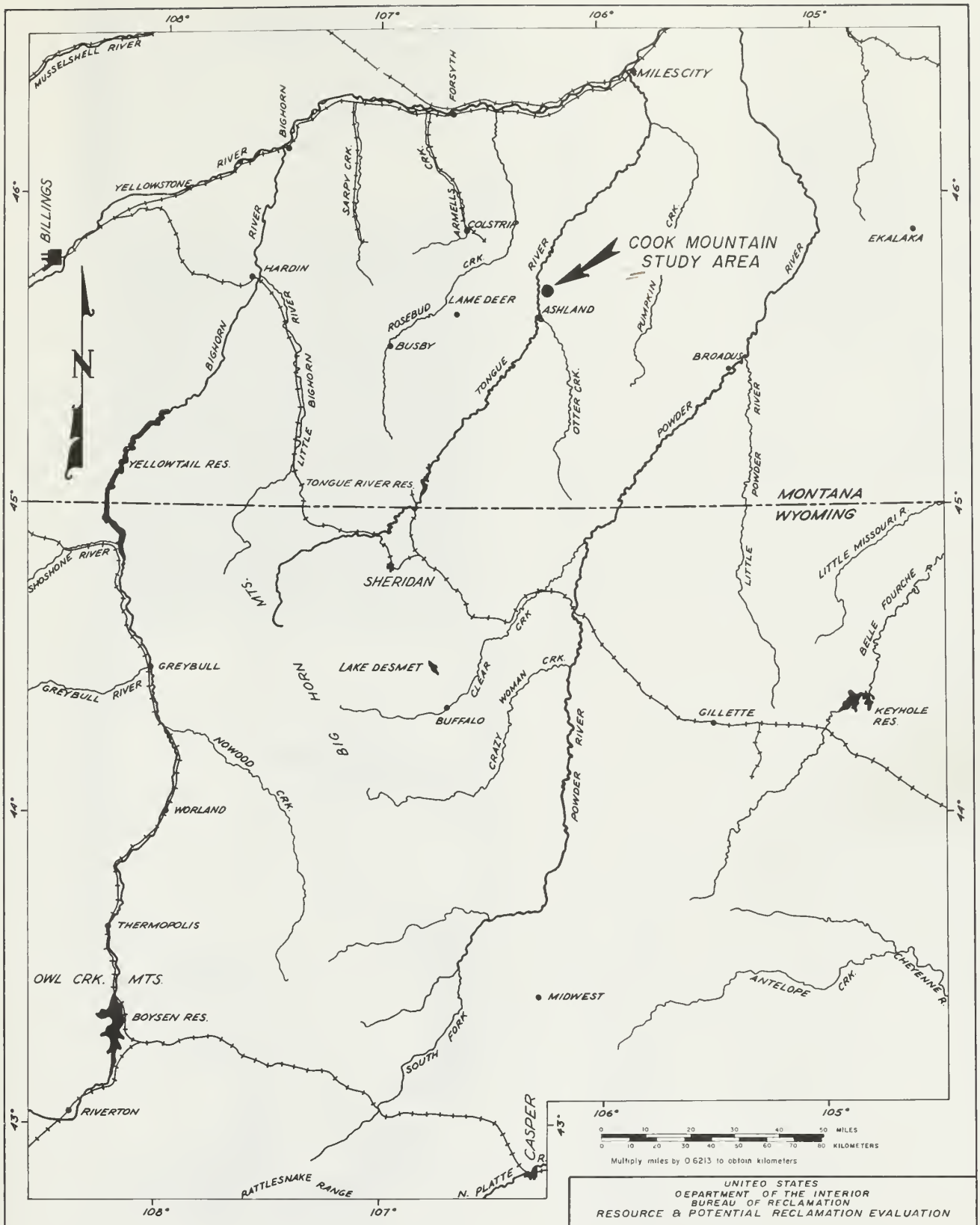
LOCATION

The Cook Mountain Study Area is located in southeastern Montana, within Rosebud and Powder River Counties, approximately 50 miles south of Miles City and about 6 miles northeast of Ashland (Plates 1 and 2).

The site is comprised of 4549.8 acres of privately-owned land (Plates 2 and 3) described as follows:

T. 2 S., R. 44 E., Section 24 (all)

T. 2 S., R. 45 E., Section 18 (all)
Section 29 (S1/2)
Section 30 (all)
Seciton 32 (all)

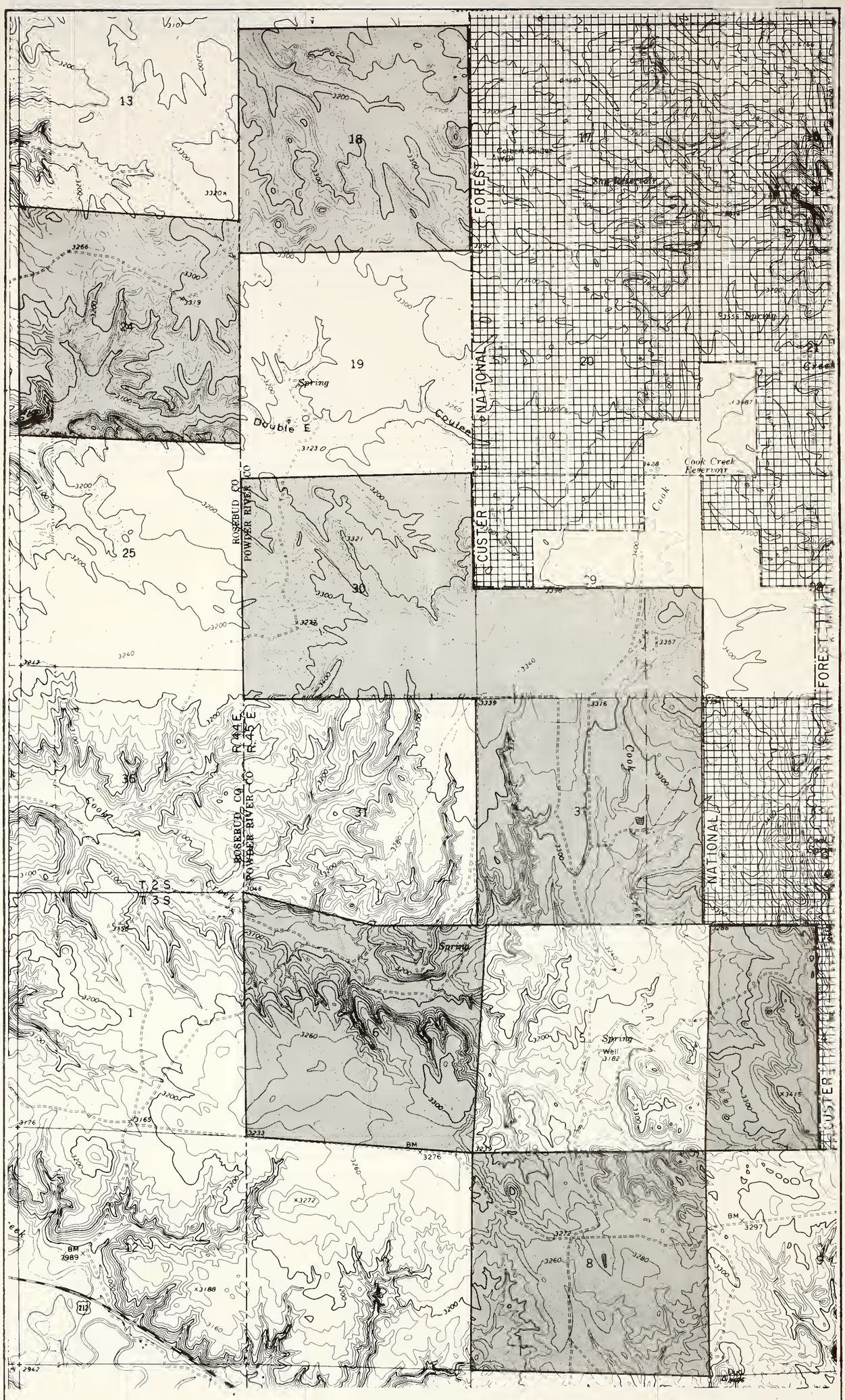


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA - MONTANA

GENERAL LOCATION MAP

DESIGNED _____ SUBMITTED _____
DRAWN G. TAUCHER RECOMMENDED _____
CHECKED _____ APPROVED _____
REGIONAL ENGINEER
BILLINGS, MONTANA OCTOBER, 1981 1305-600-197



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1 5 0 1 KILOMETER

Land owned by the Federal Government. (Custer National Forest)

(All other land is either state or privately owned).

Study area.

Topography from U.S.G.S. 7.5' Quadrangles.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA

LOCATION AND LAND OWNERSHIP MAP

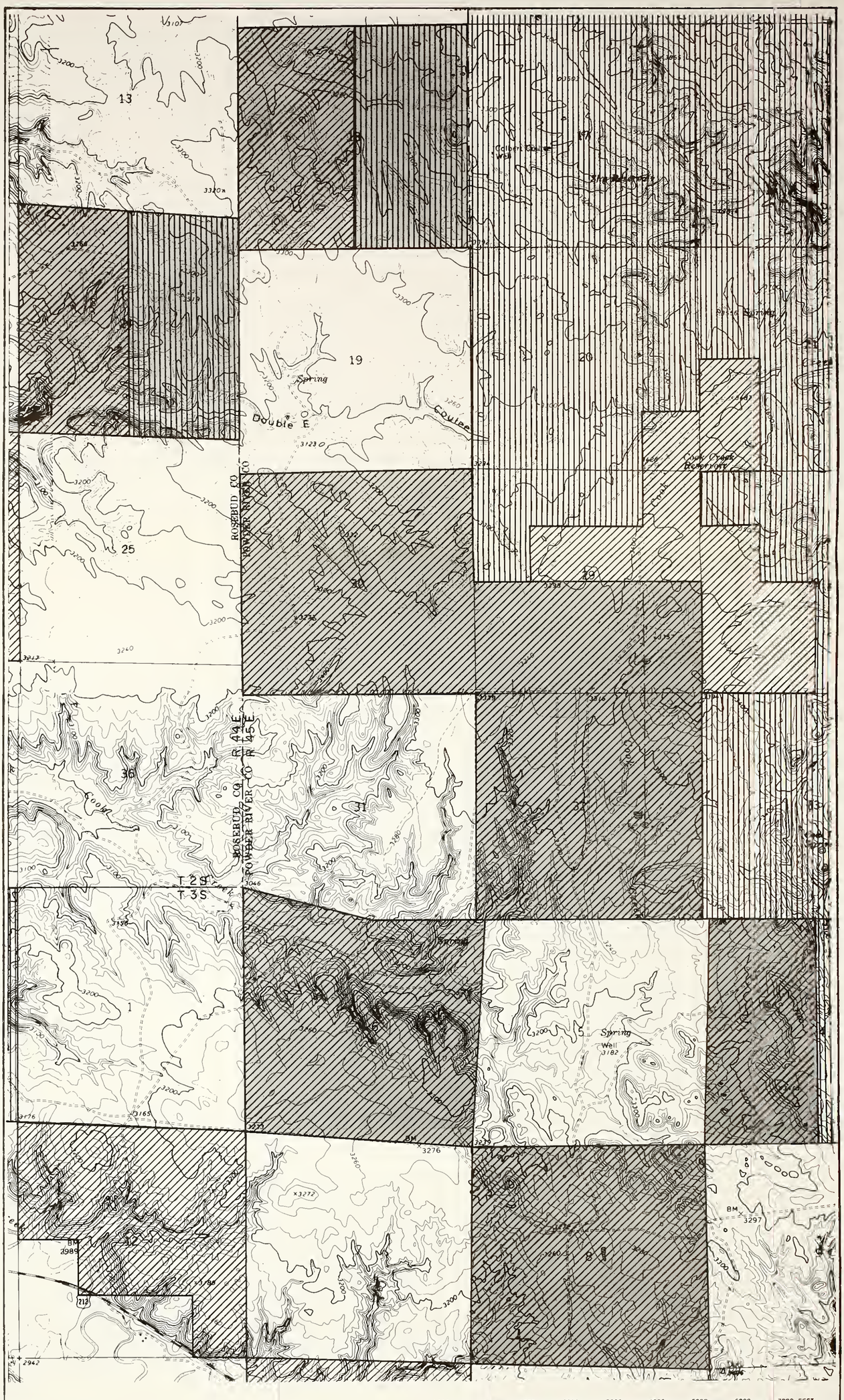
GEOLOGY F. CALCAGNO FIELD APPROVAL

DRAWN L. E. ALLSOP TECHNICAL APPROVAL

CHECKED APPROVED
REGIONAL ENGINEER

BILLINGS, MONTANA OCT., 1981 1305-600-198

Plate 2


13
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31
36
T 2S
T 3S
R 44E
R 45E
ROSEBUD CO
POWDER RIVER CO
Double E
Spring
Coulee
Colbert Coulee
Well
Shepherds
Oak Creek Reservoir
Creek
Spring
Well
3182
BM
3276
BM
3297
BM
2989
3272
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4000
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T. 3 S., R. 45 E., Section 4 (W1/2)
Section 6 (all)
Section 8 (all)

All coal within the study area is owned by the Federal Government (Plate 3).

PRESENT LAND USES

The Cook Mountain Study Area is used for cattle grazing (rangeland), timber production (forestland), and dry land farming (hay). The area also provides valuable habitat for wildlife with a high species diversity.

POSTMINING LAND USES

Postmining land uses in the Cook Mountain Study Area are expected to be similar to the present uses (rangeland, forestland, hayland). Portions of the forestland would be cleared prior to mining, with potential conversion to cropland following reclamation if the landowner(s) so desires and the Montana Department of State Lands approves this alternate land use.

RULES GOVERNING MINING AND RECLAMATION OPERATIONS

In Montana, coal mine operators must comply with all established rules pursuant to the Montana Strip and Underground Mine Reclamation Act (1973). These rules are presented in Appendix A of the "Montana Permanent Program" for regulating surface and underground mining activities.[1/]

The Montana Department of State Lands is the regulatory agency responsible for administering this program.

1/ The Montana Permanent Program was approved by the U.S. Department of the Interior, Office of Surface Mining, on April 1, 1980.

OBJECTIVE OF RECLAMATION

Montana law presently requires the coal mine operator to restore all disturbed areas, "in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses. Alternative land uses may be approved by the Department of State Lands after consultation with the landowner or the land-management agency having jurisdiction over the lands . . ." (Rule XVI, 5(c) pursuant to "The Montana Strip and Underground Mine Reclamation Act" - Montana Permanent Program).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Montana Department of State Lands, the main objective of reclamation in the Cook Mountain Study Area would be to establish a diverse vegetative cover with an interspersion of vegetative types over the reclaimed land capable of supporting livestock and wildlife. The integrity of the visual resource should be maintained.

PHYSICAL PROFILE

CLIMATE[1/]

The Cook Mountain Study Area has a continental-type climate characterized by cold winters, warm summers, and large variations in seasonal precipitation.

Precipitation

The mountains along the Continental Divide cause air masses to rise and precipitate their moisture, primarily on the windward slopes. The air masses then warm and dry as they descend the leeward slopes. As a result, a "rain shadow" is created over the eastern Montana counties. The average annual precipitation in these counties is about 13 inches.

The Broadus weather station (about 35 miles southeast of the study area) at elevation 3030 feet receives 13.8 inches of average annual precipitation; and Birney (about 28 miles southwest of the study area), at elevation 3190 feet, receives 13.7 inches in an average year.[2/]

The following mean monthly and annual precipitation values were recorded at Broadus between 1937 and 1961:

Month												
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
						(Inches)						
.50	.46	.80	1.24	2.24	3.11	1.39	1.04	1.05	.88	.67	.43	13.8

Approximately 73 percent of the average annual precipitation falls between April and September. May and June are commonly the wettest months, receiving about 39 percent of the yearly average.

Snowfall is most common between October and late April. However, small amounts (0.5 inches or less) have been recorded in May, June, and September. Although a continuous snow cover is not common in this area, the total moisture provided by snowfall may comprise as much as 23 percent of the annual precipitation in an average year.

Thunderstorms and occasional hailstorms, most common in July and August, are caused by local convective heating. A semipermanent low pressure area in the southwestern United States results in a flow of unstable air into the area, contributing to this phenomenon. Damage to range plants from hail and heavy rainfall is usually minimal. However, the more intense storms may cause severe soil erosion, especially in steeply sloping and sparsely vegetated areas.

Temperature

Based on data recorded at Broadus Between 1937 and 1961, temperature extremes of 108°F in summer and -42°F in winter may occur in this area.

1/ Data from Soil Survey of Powder River Area, Montana, Soil Conservation Service, 1971.

2/ Elevations range from about 3000 to 3415 feet in the study area.

Generally, less than 30 days a year have a maximum temperature over 80°F and 20 days or less have a minimum temperature below 0°F.

The following mean monthly and annual temperatures were recorded at Broadus (1937-1961):

Month (°F)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
18.9	23.5	31.6	44.4	54.8	62.8	71.6	70.1	58.6	47.8	32.2	24.0	45.1

The frost-free period (>32°F) ranges from 108 days at Birney to about 120 days at Broadus. The growing season for hardy grasses (>28°F) in average years begins May 10 at Birney and ends 131 days later on September 19. Following the spring rains, July is hot, dry, and windy with excessive evaporation and evapotranspiration rates. Humidity is low. Growth of native range vegetation is rapid during May and June. By mid-July, however, the available soil moisture is usually depleted and the plants mature or become dormant.

Effect of Climate on Revegetation

Climate will be an important controlling factor for revegetation in the Cook Mountain Study Area. In most years, the spring rains are adequate for establishing good stands of native vegetation. The average annual precipitation, about 13.7 inches, meets the requirements for native range plants, which grow rapidly in late spring and early summer. Consumptive use data in Table 1A indicate that native grasses could utilize about 22.5 inches of moisture if available; however, 13.9 inches, or the approximate annual average, are generally used by July 15. At this time, plant maturation or dormancy occurs.

Several hazardous climate factors that could adversely affect revegetation efforts in this study area should be recognized. These include: (1) below normal or uneven distribution of precipitation, especially during the growing season; (2) intense thunderstorms or hailstorms that damage vegetation or cause soil erosion; (3) late spring freezes, and (4) depletion of soil moisture by wind. More detailed onsite data collection will be necessary prior to mining to more accurately determine probabilities of occurrence of these factors. This data can then be used to select best possible seeding times for revegetation.

PHYSIOGRAPHY

The Cook Mountain Study Area lies in the unglaciated Missouri Plateau section of Great Plains Physiographic Province. The area is generally rolling and has been thoroughly dissected. Several prominent buttes, often capped by resistant clinker, rise above the divides which generally trend in a west-northwesterly direction through the study area. Maximum relief in the study area is 415 feet, with elevations ranging from 3415 feet in the uplands in Section 4, T. 3 S., R. 45 E. to 3000 feet in the Cook Creek drainage bottom in Section 6, T. 3 S., R. 45 E.

The study area is located between Colbert Coulee to the north and Otter Creek to the south. The study area itself is dissected by Double E Coulee and Cook Creek. All of these creeks are intermittent, with the exception of Otter Creek, and flow in a westward direction to the Tongue River located approximately 1 mile west of the area. Drainages within the study area are deeply incised into shales, sandstones, and coalbeds of the Paleocene Fort Union Formation. A topographic map of the area is shown on Plate 2.

Potential Consumptive Use of Moisture and Available Moisture - Native Grasses 1/

Cook Mountain Study Area

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (F)	Monthly Requirement Inches	Moisture Reserve Inches 2/	Precipitation Inches	Difference Inches 3/
May 4					+4.04		
	May 17	13	54.6	2.80		2.23	+3.47
June					+3.37		
	June 15	42	63.1	4.75		3.13	+1.85
July					+1.85		
	July 15	72	71.2	6.36		1.36	-3.15 4/
August					-3.15		
	Aug. 15	103	69.8	5.52		1.08	-7.59
Sept.					-7.59		
	Sept. 13	131	58.2	3.05		1.20	-9.44
Sept. 27		145					
				22.48		9.00	

1/ Computed by Blaney-Criddle Method using the Broadus Weather Station - Latitude 45 degrees 26'N
2/ Moisture Reserve = Summation of precipitation (Oct. to April) = 5.05 x 0.80 = 4.04 inches
3/ Difference = Moisture Reserve plus precipitation minus moisture use.
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, the plants use the available moisture by July 15 and mature and become dormant.

Table 1A

GEOLOGY

Regional Geology

The Cook Mountain Study Area lies in the northern part of the Powder River Basin in southeastern Montana. This basin, a part of the unglaciated portion of the Great Plains Physiographic Province, is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles in width, bounded on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales was deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods with deposition usually occuring in a marine environment. Deformation of strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued throughout the Paleocene and gradually ended in Eocene Time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. A generalized regional geologic map is shown on Plate 4.

Area Geology

Investigations

All of the area involved in the Cook Mountain Study Area has been mapped by the U.S. Geological Survey and the Montana Bureau of Mines and Geology. Publications covering these investigations are listed in the bibliography.

Logs of drill holes used to gather information for this report were obtained from several sources. Sixteen drill holes ranging from 120 to 340 feet in depth were completed during June and July of 1978 by Intrasearch, Inc. of Billings, Montana. Five U.S. Geological Survey drill holes ranging from 92 to 313 feet in depth were completed in July 1979. In addition, information from three Montana Bureau of Mines and Geology drill holes (Matson and Blumer, 1973) ranging from

186 to 230 feet in depth was also used. The locations of these drill holes are shown on the Geologic and Investigations Map, Plate 6. Geologic cross sections, correlating coalbeds, are shown on Plates 7 and 8. Detailed geologic logs for selected drill holes in the area are listed on Plates 9 through 24 in Appendix B.

Detailed geologic mapping on a scale of 1 to 24,000 was completed on a topographic map and is shown on Plate 6. Although geologic mapping was completed for all sections as shown on Plate 6, coal resources were evaluated only for those sections, or portions of sections, defined as the study area on the Location and Land Ownership Map, Plate 2. A discussion of area geology will include information gained from all sections mapped, as shown on Plate 6. Plate 5 shows a generalized stratigraphic column of coalbeds mapped or penetrated by drilling.

Stratigraphy

Sedimentary rocks exposed in the study area range from the coal bearing Fort Union Formation of Paleocene Age to alluvial deposits of Holocene Age which mantle valley floors of the major tributaries.

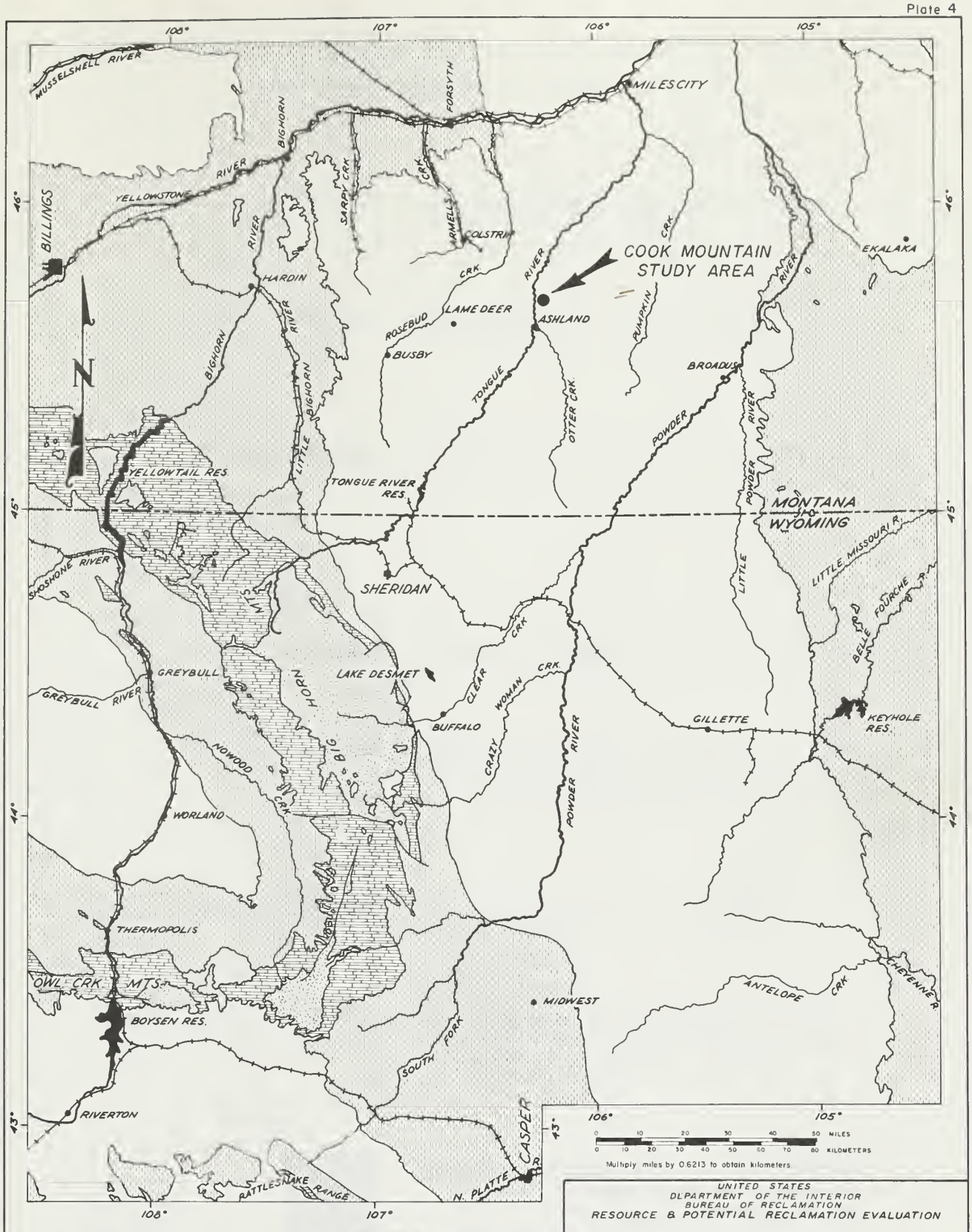
Paleocene Series

The Fort Union Formation consists of three lithologic units which include, from bottom to top, the Tullock, Lebo Shale and Tongue River Members. Only the Tongue River Member will be discussed in this report as the lower members were not penetrated by drilling, nor do they outcrop within the study area.

The Tongue River Member consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale and coal with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and unce-mented except for lenticular, concretionary masses of small lateral extent. Shales vary from soft, plastic clayshale to moderately indurated claystone. The shale and siltstone zones break down readily and form slopes below sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling, and variation in bedding thickness. Laboratory analyses conducted on core samples from other study areas indicate that chemical and physical properties of the bedrock cannot accurately be projected between drill holes. Weathered exposures are pale olive or yellowish gray in color, while fresh core samples vary from light to dark gray. The Tongue River sediments were deposited in a continental environment which included swamps conducive to the production of thick coalbeds. Coal and carbonaceous zones serve as excellent marker beds as they can generally be traced laterally over great distances. The Tongue River Member has a total thickness in the Ashland Coalfield ranging from 1,150 feet in the east, to 1,600 feet in the west. Drilling at the Cook Mountain Study Area penetrated the upper 580 feet of the Tongue River Member.

Holocene Series

Alluvial deposits consisting of clay, silt, sand and gravel cover bedrock to depths of 30 feet along valley floors in the study area (Plate 6). Gravels are generally composed of hard shale, sandstone or clinker fragments.



● COOK MOUNTAIN STUDY AREA

CENOZOIC
MESOZOIC
PALEOZOIC
PRE-CAMBRIAN

NOTE: COMPILED FROM STATE GEOLOGIC MAPS

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RESOURCE & POTENTIAL RECLAMATION EVALUATION

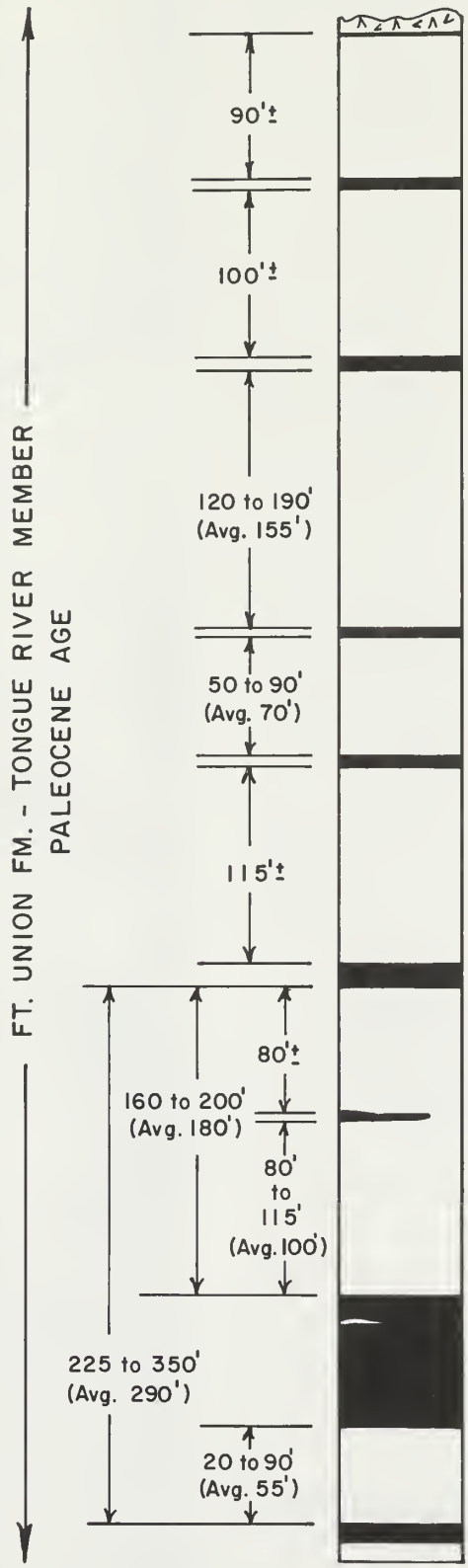
COOK MOUNTAIN STUDY AREA – MONTANA

GENERALIZED REGIONAL GEOLOGIC MAP

GEOLOGY	GJ TAUCHER	SUBMITTED	
DRAWN	GJ TAUCHER	RECOMMENDED	
CHECKED		APPROVED	

BILLINGS, MONTANA — OCTOBER, 1981 — 1305-600-200

STRATIGRAPHIC COLUMN - COALBEDS OF THE COOK MOUNTAIN STUDY AREA ASHLAND COALFIELD, MONTANA



GARFIELD COALBED - Caps highest (clinker) peak in Ashland coalfield.

FERRY COALBED - 3 to 7.6 feet thick (F COALBED of U.S.G.S. Bull. 831-B.)

LOWER COOK COALBED - 5 to 12 feet thick.

UPPER E COALBED - 2.5 up to 16 feet thick.

C and D COALBEDS - 3 to 6 feet thick.
C COALBED contains abundance of carbonized tree remains (little economic importance).

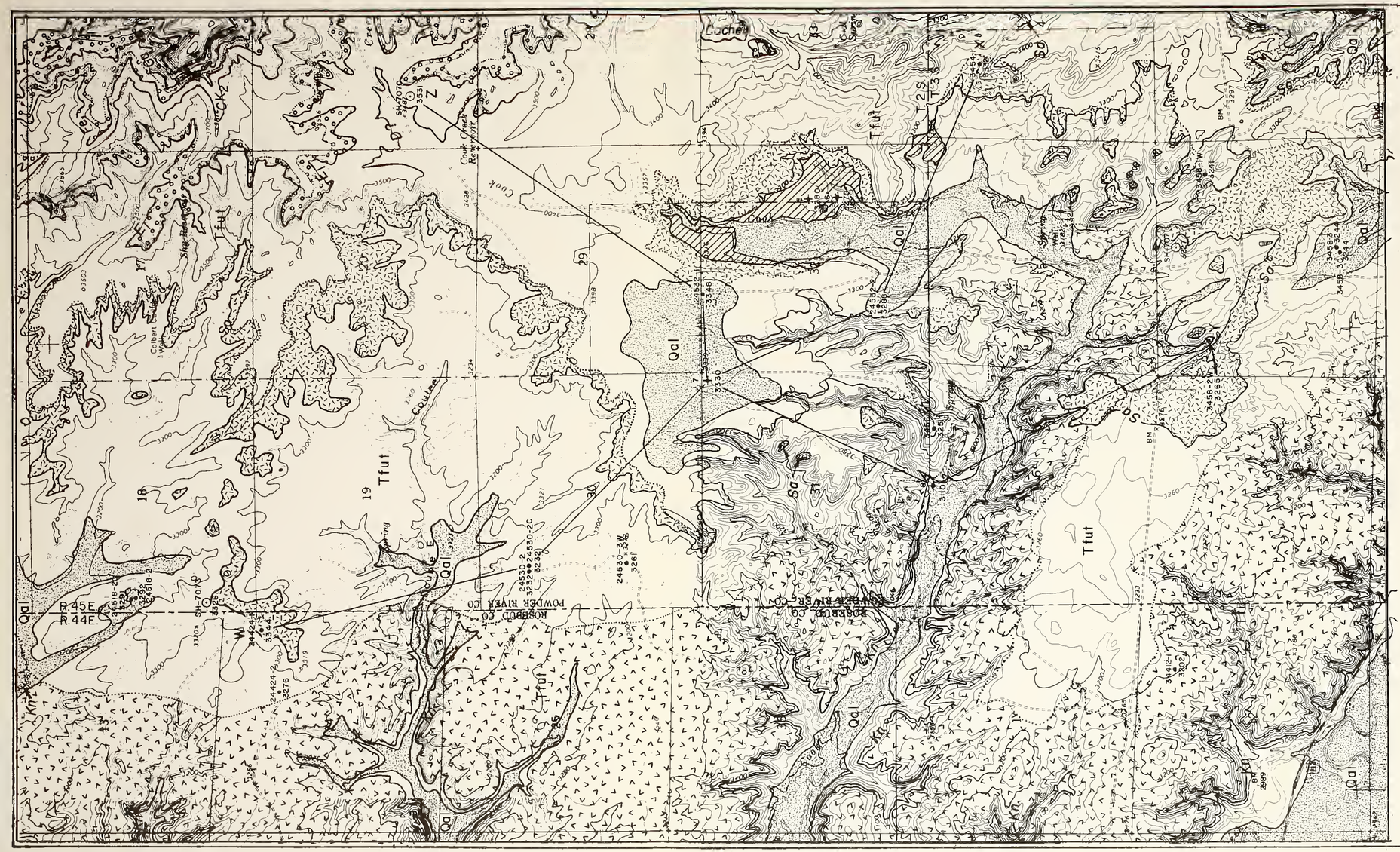
SAWYER COALBED - 10 to 14 feet thick.

LOCAL COALBED - Up to 4 feet thick. Often present as coal stringers (especially to south). (Leebed (?) of U.S.G.S. Bull. 831-B.)

KNOBLOCH COALBED - 46' to 59' thick (Averages 53' thick). Thins northward. Splits up to 3.3' thick in isolated locations approximately 6 feet below top of coalbed.

FLOWERS-GOODALE COALBED - 8± feet thick.

NOTE: Multiply feet by 0.3048 to obtain meters.


Cache
Cook
Colbert
Tfut
Qal
Sa
Qa
T2S T3
R.45E
R.44E
POWDER RIVER CO
ROSEBUD CO
SH-70
Cook Creek Reservoir
Site Headquarters
Coulee
Spring
24530-2
3232
24530-2W
3261
24530-3W
3261
24530-2E
3232
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3276
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24518-2
3252
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3261
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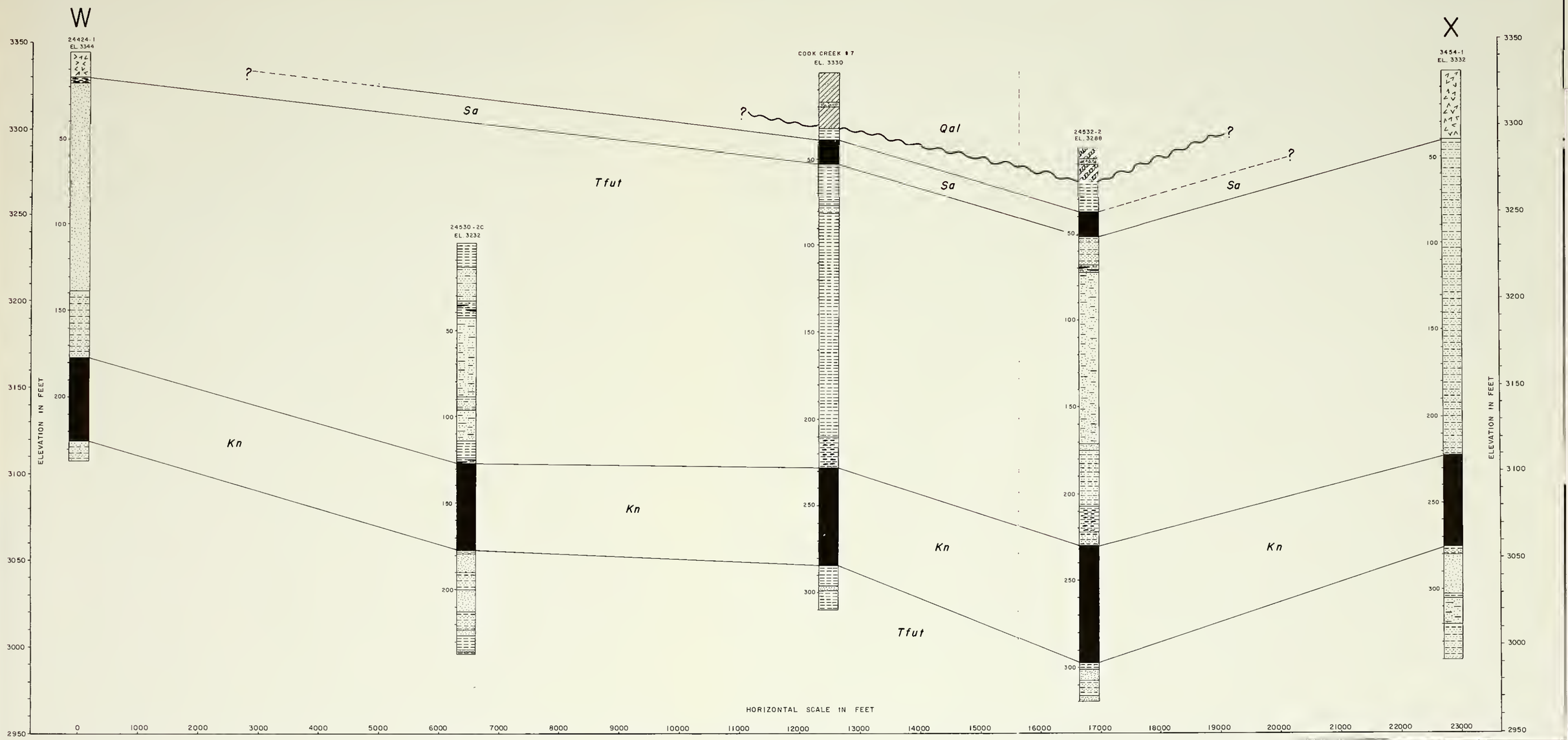

EXPLANATION

- CLAY
- GRAVEL (clinker derived)
- SHALE (includes claystone)
- SILTSTONE
- SANDY SILT
- COAL STRINGERS
- COALBED
- CLINKER
- SANDSTONE
- CARBONACEOUS SHALE

(NOTE: Symbols may be combined in cases of multiple lithologies.)

Qal - Undifferentiated Quaternary alluvium, coluvium and gravel depasits.

Tfut - Tertiory Fort Union Formation, Tongue River member.

Coalbeds (Tfut)

So Sowyer Coalbed

Kn Knobloch Coalbed

NOTES : Information presented in feet, multiply feet by 0.3048 to obtain meters.

Limits of Geologic Section shown on Plate 6.

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COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
GEOLOGIC SECTION W-X

DESIGNED F. Caicagno, Jr. FIELD APPROVAL
DRAWN C.J.R. TECHNICAL APPROVAL
CHECKED APPROVED
REGIONAL ENGINEER

BILLINGS, MONTANA MAY 1981

1305-600-202

EXPLANATION

- SILTY CLAY
- SILT
- SILT WITH SAND, GRAVEL AND COBBLES
- SANDY SILT
- GRAVEL (clinker derived)
- CLAY
- SHALE (includes claystone)
- SILTSTONE
- SANDSTONE
- CARBONACEOUS SHALE
- COAL STRINGERS
- COALBED
- CLINKER
- INFORMATION UNAVAILABLE

(NOTE: Symbols may be combined in cases of multiple lithologies)

Qal - Undifferentiated Quaternary alluvium, colluvium and gravel deposits.

Tfut - Tertiary Fort Union Formation, Tongue River Member.

Coalbeds (Tfut)

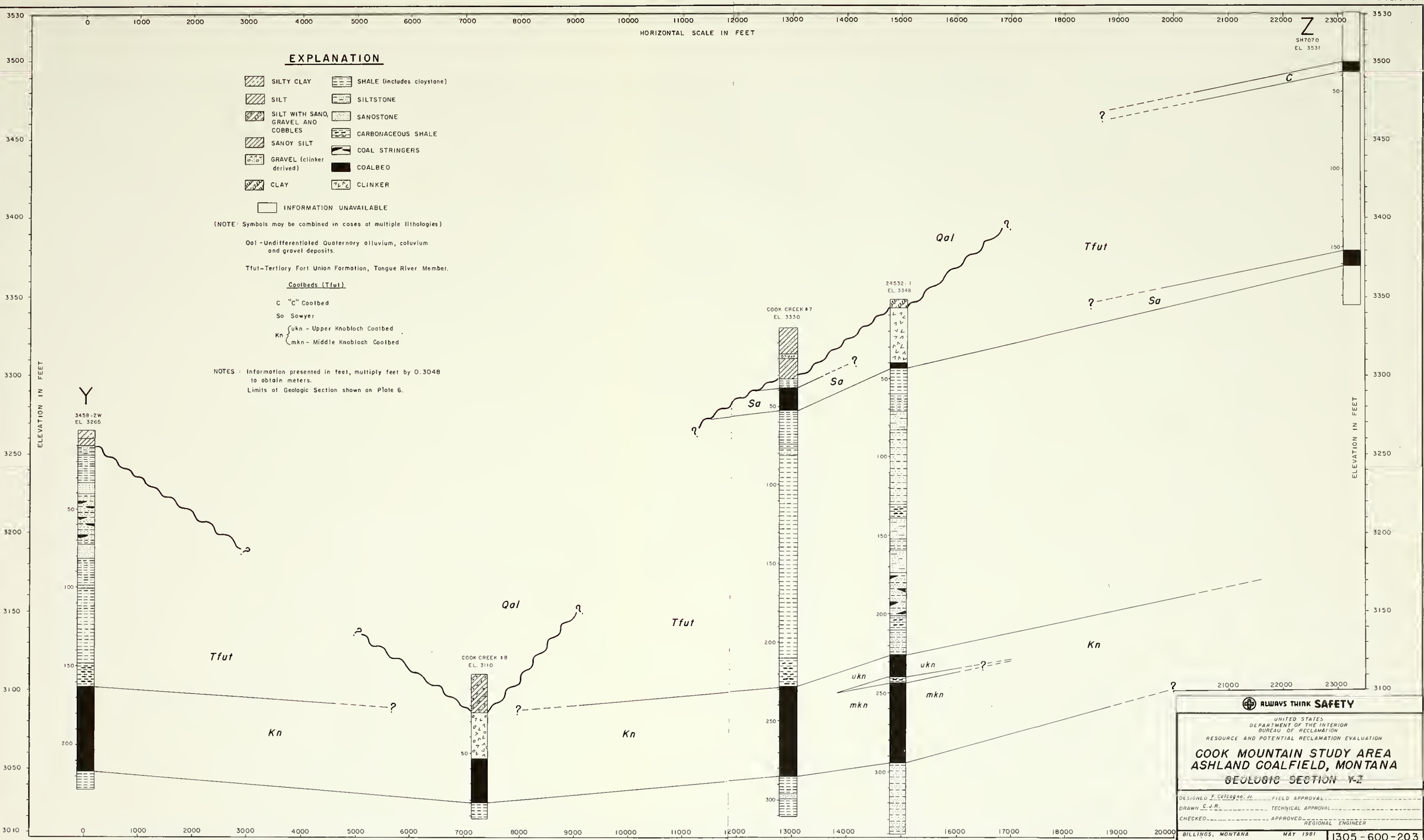
C "C" Coalbed

So Sawyer

Kn { ukn - Upper Knobloch Coalbed; mkn - Middle Knobloch Coalbed

NOTES: Information presented in feet, multiply feet by 0.3048 to obtain meters.

Limits of Geologic Section shown on Plate 6.



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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
GEOLOGIC SECTION Y-Z

DESIGNED F. Calcagno, Jr. — FIELD APPROVAL
DRAWN C.J.R. — TECHNICAL APPROVAL
CHECKED — APPROVED — REGIONAL ENGINEER

BILLINGS, MONTANA — MAY 1981 — 1305-600-203

Clinker

One striking feature of the Fort Union Formation is the resistant clinker zones, locally called "scoria," that cap ridges and buttes or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of coalbeds along and back from the outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of coal that has burned. A coalbed 30 feet thick will produce clinker zones 50 to 75 feet thick. The clinker is highly permeable and locally supplies water for springs and wells. The two main clinker zones present in the study area were produced by burning of the Knobloch and Sawyer Coalbeds. Outcrops of the Knobloch clinker zone occur mostly along valley walls, while the Sawyer clinker characteristically caps buttes and ridges within the area. About 20 percent of the Knobloch and 80 percent of the Sawyer Coalbeds have been removed either by erosion or burning from the study area, Plate 6.

In addition to the Knobloch and Sawyer clinker zones, five relatively thin coalbeds outcropping in the northeastern portion of the mapped area have produced thin clinker zones. The location of the clinkered areas are shown on the Geologic and Investigations Map, Plate 6. Subsurface investigations have shown that not all coal has burned beneath clinkered areas. An extensive drilling program would be required to locate and delineate any such deposit. For the purpose of this report, the contact between baked and unbaked rock is assumed to be vertical and that all coal underlying clinker has burned.

Coalbeds

Nine persistent coalbeds crop out or were penetrated by drilling in the vicinity of the Cook Mountain Study Area. Descriptions of these beds are found on the generalized stratigraphic column, Plate 5. Seven beds, the Knobloch, Sawyer, C and D Coalbeds, Upper E, Lower Cook, Ferry, and Garfield, were mapped in the study area as shown on the Geologic and Investigations Map, Plate 6. Only two beds, the Knobloch and Sawyer, which occur beneath the area generally within 250 feet of the surface, are discussed in this report with respect to economic significance.

The Knobloch Coalbed averages approximately 53 feet thick in the study area, ranging from 59 feet thick in the south, to 46 feet thick in the north. Overburden thicknesses over unclinkered Knobloch range from about 10 feet in Section 19, T. 2 S., R. 45 E., to an extreme of over 950 feet in Section 16, T. 2 S., R. 45 E. Contours showing depths to the top of the Knobloch Coalbed and thicknesses of overburden are plotted on the Overburden Thickness Map, Plate 25. Although the Knobloch Coalbed is known to split into an Upper, Middle and Lower bench in various locations, only three drill holes encountered splits in the Knobloch within the study area; see Plates 5, 7 and 8, and the geologic logs, Plates 9 through 24, for details.

The Sawyer Coalbed averages about 14 feet thick in the study area. The stratigraphic interval between the bottom of the Sawyer and top of the Knobloch beds ranges from 160 feet to slightly over 200 feet. Overburden thicknesses over unclinkered Sawyer range from near 0 feet in Sections 31 and 32, T. 2 S., R. 45 E., to over 750 feet in Section 16, T. 2 S., R. 45 E. Structure contours on the

top of the Sawyer and overburden thickness contours indicating the depth to coal are shown on Plate 26. As with the Knobloch Coalbed, the Sawyer is known to split in various locations, however, no drill holes within the study area encountered any splits in the Sawyer Coalbed.

Structure

The study area is located in the northern part of the Powder River Basin. Regional dips are toward the southwest away from the Miles City Arch at about 25 feet per mile. The chief structural features in the region are the broad, northeastward plunging Tongue River Syncline, whose axis follows the Tongue River Valley, and a northwestward trending unnamed syncline, whose axis passes about 2 miles south of Ashland. Minor faulting has also been noted in the region. Approximately 10 miles to the northwest, normal faults trending nearly parallel to the Lake Basin fault zone have been observed with throws up to 75 feet. Small local faults have also been encountered in core material from the EMRIA Shy/6 Study Site, located approximately 7 miles to the south. These faults are generally restricted to weak, plastic carbonaceous shales immediately above or below coalbeds. Displacements could not be determined, but probably do not exceed 5 feet.

Structure contours drawn on the top of the Knobloch and Sawyer Coalbeds (Plates 25 and 26) show an average dip of 17 feet per mile to the southwest. These contours were prepared using information obtained from the drill holes described previously and from outcrops of coalbeds and clinker. Minor folds and flexures are apparent throughout the study area, as well as small structural domes and basins. In general, there is a close correlation of structures within the Knobloch and Sawyer Coalbeds throughout the study area. These minor features could be the result of differential compaction of underlying and adjacent strata. Other local structural features which do not continue with depth may be depositional rather than deformational features. Although no direct evidence of faulting was encountered within the study area, minor faults should be anticipated due to readjustment from coalbed compaction.

Paleontology

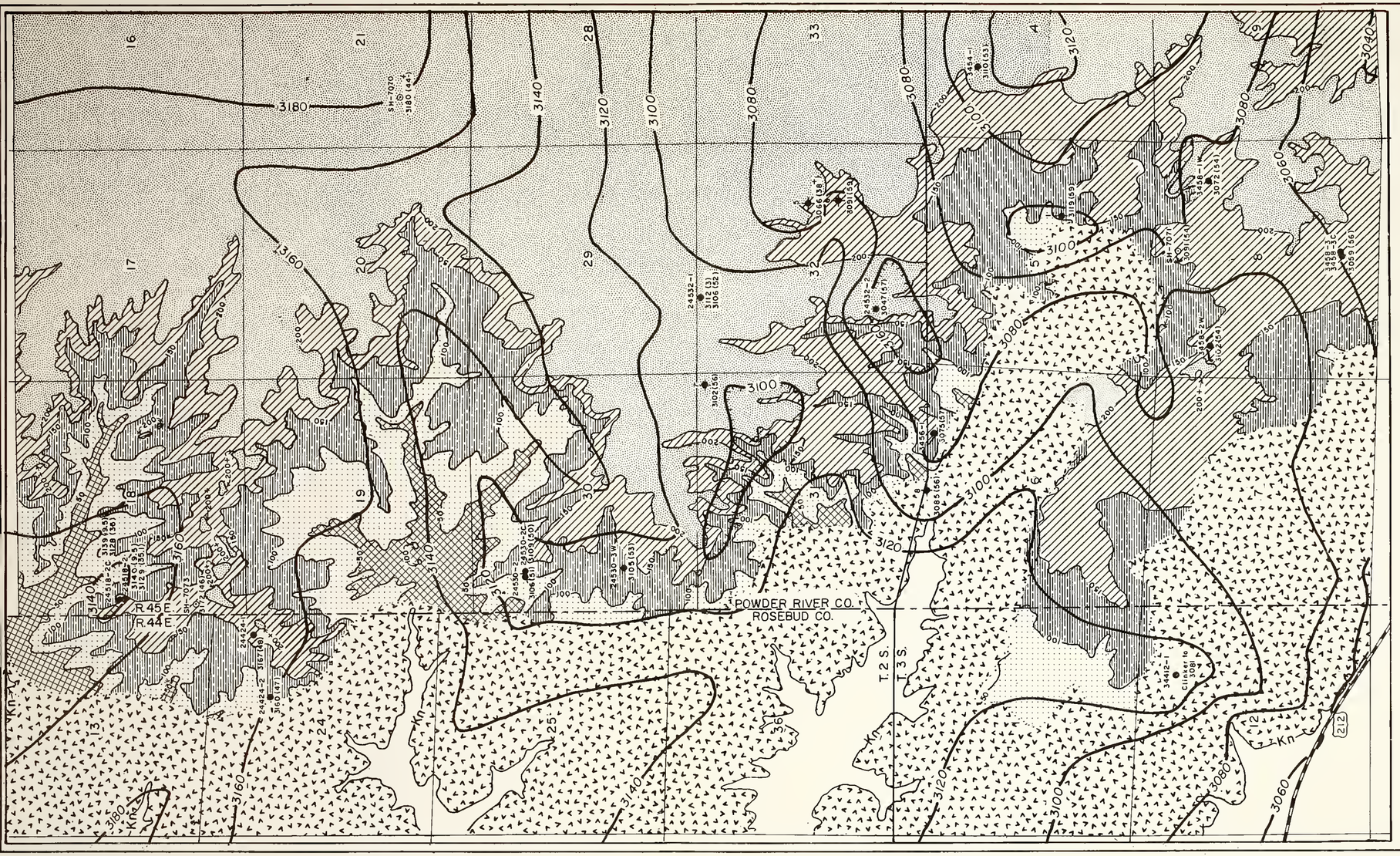
Occasional poorly silicified tree fragments and pieces of unidentified calcareous shells were found on the surface area. However, nothing of significance was observed. Significant paleontological sites were not located during the mapping of the area.

Engineering Geology

Slope Stability

Engineering property tests were not conducted on bedrock samples from the Cook Mountain Study Area. However, physical properties of these sediments should be similar to the results obtained by the U.S. Geological Survey for Fort Union samples at the Otter Creek Study Site (EMRIA Report No. 1).

Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, especially along beds of weak, plastic, carbonaceous shales which are typically cut by



EXPLANATION

- Clinker-oreo where Knobloch Coalbed hos burned.
- OVERBURDEN ABOVE KNOBLOCH COALBED
  - 0 to 50 feet
  - 50 to 100 feet
  - 100 to 150 feet
  - 150 to 200 feet
  - Over 200 feet
- —Kn— Bose of Knobloch Coolbed.
- —3120— Structure contour on top of Knobloch Coolbed (feet).
- —100— Contour showing depth to Knobloch Coolbed (feet).
- ..... Inferred limit of burning of coolbed.
- * Includes interburden, coal, ond overburden.
- ● Intraseorch drillhole.
- ✦ U.S.G.S. drillhole.
- ⊙ Montono Bureau of Mines & Geology (Bull. 91) drillhole.

NOTES

Elevations odjacent to drillholes ore for top of Knobloch Coolbed.

Dual elevotions represent tops of upper ond lower benches where Knobloch is split.

Thickness of coal is shown in parenthesis.

Multiply feet by 0.3048 to obtain meters.

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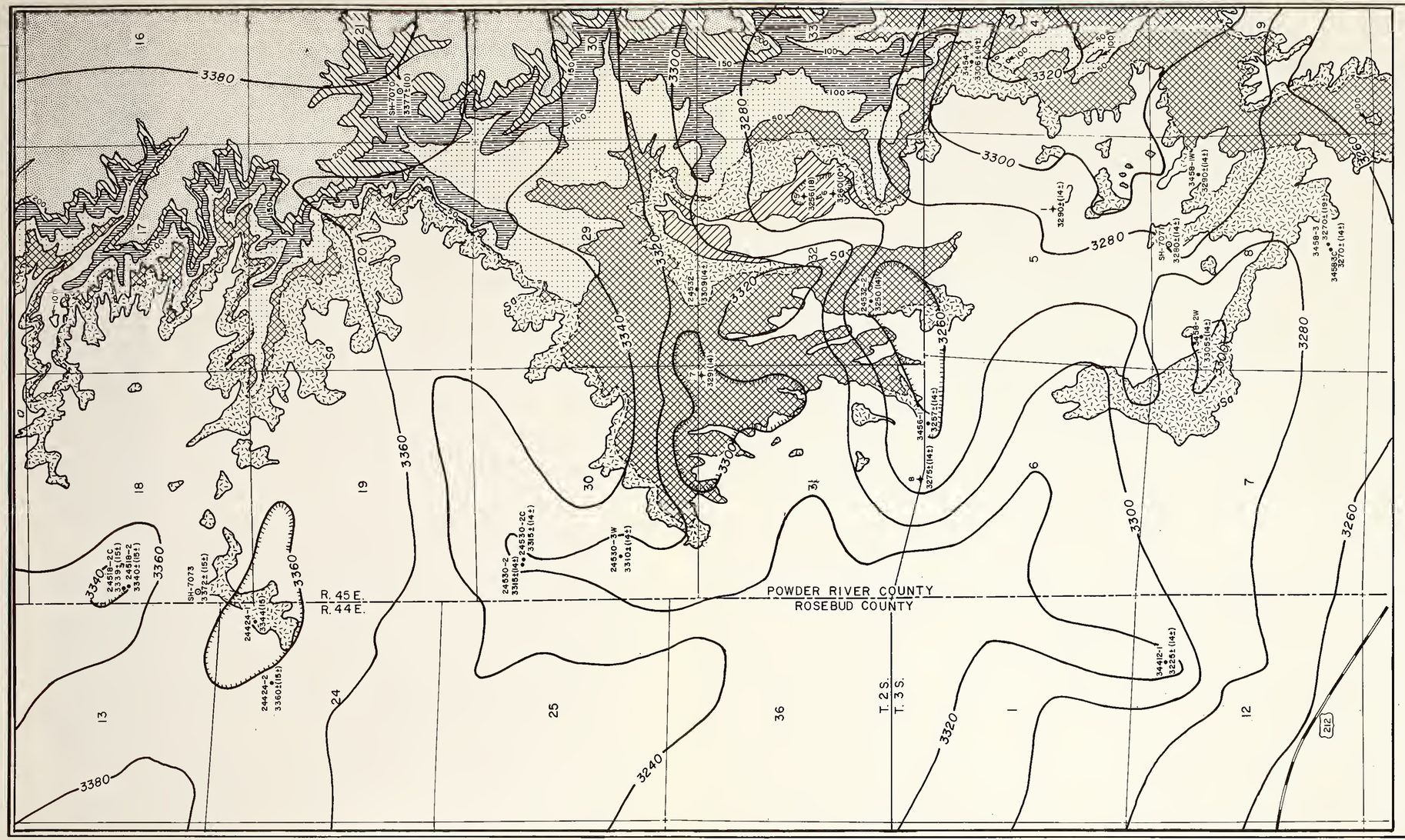
OVERBURDEN THICKNESS MAP
KNOBLOCH COALBED

GEOLOGY F. CALCAGNO JR. FIELD APPROVAL
DRAWN GARY VETTER TECHNICAL APPROVAL
CHECKED APPROVED REGIONAL ENGINEER

BILLINGS, MONTANA MAY 1981 | 1305-600-204



EXPLANATION

- Clinker – Areo where Sawyer Coalbed has burned
- Probably eroded or clinkered

* OVERBURDEN ABOVE SAWYER COALBED

- 0–50 feet
- 50–100 feet
- 100–150 feet
- 150–200 feet
- Over 200 feet

—So— Base of Sawyer Coalbed

—3280— Structure contour on top of Sawyer Coalbed (feet).

—100— Contour showing depth to Sawyer Coalbed (feet).

Inferred limit of burning of coalbed.

* Includes interburden, cool, and overburden.

• Introseorch drill hole

✦ U.S.G.S. drill hole

⊙ Montana Bureau of Mines and Geology (Bull. 91) drill hole.

NOTE: Elevations adjacent to drill holes are for top of Sawyer Coalbed. Thickness of cool shown in parenthesis.

Multiply feet by 0.3048 to obtain meters.

1000 0 1000 2000 3000
SCALE OF FEET

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OVERBURDEN THICKNESS MAP
SAWYER COALBED

GEOLOGY F. CALCAGNO, JR. FIELD APPROVAL
DRAWN M.J. Tweedy Jr. TECHNICAL APPROVAL
CHECKED APPROVED
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inherent slickensides. Adequate drainage should be maintained to relieve pore water pressures in the overburden as mine excavations progress.

Saturated alluvial deposits and uncemented siltstones and fine grained sandstones will readily erode and flow into excavations. This problem was encountered in drilling other sites when the walls of holes collapsed and sloughed. Depth of excavation below the water table will be limited until these materials are unwatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of slopes.

Studies conducted at the Otter Creek Site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet wide designed on the slope surface.

Overburden Expansion

The degree to which the topography wil be altered during surface mining depends upon many things - the most important being the (1) depth and thickness of coal being mined, (2) manner in which the spoil is returned to the pit, and (3) moisture content of the overburden. Overburden expands as the materials are broken up during mining and an increase in void space occurs. The increase in volume (bulking) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will expand about 25 percent. In some cases, the surface of the replaced overburden may actually be higher in elevation after mining.

Table 1 shows the anticipated change in topography that would occur in the study area at selected drill holes if the Knobloch and Sawyer Coalbeds are surface mined. This assumes that, (1) stripping would occur to depths of 298 feet, (2) 100 percent of the coal would be removed, (3) overburden is replaced on a cut-by-cut basis, (4) spoils are smoothly graded, and (5) overburden expands 25 percent.

Instability of the Postmining Landscape[1/]

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains - they are: (1) areawide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur. One or more of these types of instability may occur in the Cook Mountain Study Area.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

1/ Groenewold, G.H., and Rehm, B.W., 1980.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks were concentrated by final, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoil.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like the other instability problems, most commonly develops in areas contoured by dozers. Scraper contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

Weathering Tests

Weathering tests were not conducted on core samples collected from the Cook Mountain Study Area; however, results from tests conducted on samples from the Otter Creek Study Site, located approximately 7 miles to the southeast, indicated that the freezing-thawing condition generally caused more weathering or breakdown than wetting-drying. Of the 17 samples tested, only 4 (24 percent) exhibited sufficient breakdown to attain the texture required for topsoil, that is, 30 percent by weight of the soil passing the No. 10 screen. In the field, however, these materials, primarily shales, will probably weather at different rates, and thus will require various methods of handling, storing, and processing before they are suitable for use as topsoil in revegetation.

Seismic Hazard

The Yellowstone Park area is the most active seismic region within 300 miles of the Cook Mountain Study Area. The largest earthquake (7.1 Richter) recorded in this area occurred at Hebgen Lake, Montana, on August 17, 1959, a distance of

ELEVATION CHANGES DUE TO BULKING

Drill Hole	Depth of Cut (1)	Thickness of Coal Removed (2)	Thickness of Replaced Overburden (3)	Difference in Elevation (4)
1	154 ft.±	59 ft.±	119 ft.±	-35 ft.±
6	238	59	224	-14
7	284	70	268	-16
8	81	27+	68	-13
24424-1	225	48	221	- 4
24518-2C	198	44	193	- 5
24530-2C	177	50	159	-18
24530-3W	209	53	195	-14
24532-1	294	59	294	0
24532-2	298	71	284	-14
3454-1	275	53	278	+ 3
3456-1	233	57	220	-13
3458-1W	224	54	213	-11
3458-2W	217	54	204	-13
3458-3C	241	56	231	-10
SH7071	190	54	170	-20
SH7073	200	46	193	- 7

(1) Base of Knobloch Coalbed
(2) Includes 100 percent of Knobloch and Sawyer Coalbeds
(3) Overburden x 1.25 (bulking factor) = Replaced Overburden
(4) Multiply feet by 0.3048 to obtain meters

253 miles from the study site. Although considerable damage occurred near the epicenter, the quake was not readily noticed in the Powder River Basin. Forty-five earthquakes of moderate intensity (V to VII on the Modified Mercalli Intensity Scale) have occurred in Wyoming since 1894. Most of these have been centered in the northwestern part of the State. Between 1900 and the end of 1970, there were 113 earthquakes of Intensity V MM or greater reported in Montana. The majority of these quakes occurred in the southwestern part of the State.

The Cook Mountain Study Area is located in the Algermisson Seismic Risk Zone 1 in which minor damage could result to structures from Intensity V to VI (Modified Mercalli Intensity Scale) earthquake shocks. Earthquakes with intensities of V MM or greater that have occurred during historic times within 200 miles of the site are listed below:

Date	Intensity (Modified Mercalli)	Distance From Cook Mountain	Located Near
June 25, 1894	V	190 miles	Casper, WY
October 11, 1895	IV-V (2)	188	Hill City-Keystone, SD
November 14, 1897	VI-VII	190	Casper, WY
November 17, 1925	V	82	Bighorn, WY
February 13, 1928	V	176	Thermopolis, WY
November 16, 1928	V	185	Custer, SD
June 26, 1966	VI	193	Rapid City, SD

COAL RESOURCES

Estimation of Coal Resources

Coal resource estimates have been prepared for the Knobloch and Sawyer Coalbeds of the Paleocene Fort Union Formation within the Cook Mountain Study Area, using standard procedures. This report provides all pertinent geologic information for the entire area shown on Plates 6, 25 and 26; however, coal resource estimates have been computed for only those sections, or portions of sections, designated as the Cook Mountain Study Area as defined on the Location and Land Ownership Map, Plate 2. These sections are:

T. 2 S., R. 44 E., Section 24 (all)

T. 2 S., R. 45 E., Section 18 (all)
Section 29 (S1/2)
Section 30 (all)
Section 32 (all)

T. 3 S., R. 45 E., Section 4 (W1/2)
Section 6 (all)
Section 8 (all)

The term "coal resources" is defined as the estimated quantity of coal that is currently or potentially economically mineable.

Coal Analyses

Several variables are used to determine the quality and quantity of coal resources. These variables include the rank and weight of the coal, the thickness of the coal deposit, and the thickness of the overburden.

Rank and Weight

Tables 2 and 3 provide summaries of coal analyses for the Knobloch and Sawyer Coalbeds, respectively. The Montana Bureau of Mines and Geology analyzed the Knobloch Coalbed in one drill hole (SH-7071) within the Cook Mountain Study Area. Analyses for the Knobloch from past EMRIA study areas completed along the Otter Creek Valley are also shown in Table 2. The results indicate that the Knobloch has a heating value of 8,666 Btu (as received) within the study area (average Btu of Knobloch from nearby EMRIA studies is 8,340). The ash and sulfur contents as received are 4.7 and 0.12 percent (5.5 and 0.22 percent for nearby EMRIA studies), respectively. This indicates that the rank of the Knobloch coal is subbituminous C.

The average as received ash and sulfur contents of the Sawyer Coalbed from samples collected in the Ashland Coalfield are 4.9 and 0.44 percent, respectively. The average heating value (as received) for the Sawyer is 7,894 Btu. This value lies slightly below the dividing value between lignite A and subbituminous C coals, hence, the Sawyer coal in the Cook Mountain Study Area has been designated a rank of lignite A for purposes of calculating resources.

The average weight of subbituminous C and lignite A coal is 1,770 tons per acre-foot, or a specific gravity of 1.30.

Summary of Coal Analyses

Knobloch Coalbed

LOCATION	PROXIMATE ANALYSIS (as rec'd.) % Moisture	% Ash	% Sulfur	Btu Per Pound	RANK
COOK MOUNTAIN STUDY AREA					
SH-7071 Sec. 8, T. 3 S., R. 45 E.	27.32	4.7	0.12	8,666	Subbituminous C
OTHER EMRIA STUDY AREAS ALONG OTTER CREEK					
Otter Creek 1/	30.03	5.5	0.15	8,110	Lignite A
SHY/6 2/	28.04	6.3	0.23	8,485	Subbituminous C
Newell/28 3/	26.39	5.4	0.20	8,790	Subbituminous C
Otter Creek East 4/	28.00	6.4	0.28	8,476	Subbituminous C
Chromo/4 5/	31.90	3.7	0.32	8,290	Lignite A
Dam Creek 6/	32.32	6.4	0.24	7,892	Lignite A
Average	29.14	5.5	0.22	8,340	Subbituminous C

Footnotes:

(Distance from Cook Mountain Study Area)

1/ 7.0 miles SE

2/ 7.5 miles S

3/ 11.3 miles S

4/ 12.0 miles SSE

5/ 13.5 miles S

6/ 15.0 miles SSE

Summary of Coal Analyses

Sawyer Coalbed

LOCATION [1]	PROXIMATE ANALYSIS (as rec'd) % Moisture	% Ash	% Sulfur	Btu Per Pound	RANK
COOK MOUNTAIN STUDY AREA					
SH-7070 Sec. 21, T. 2 S., R. 45 E.	32.91	4.9	0.40	7,814	Lignite A
ASHLAND COALFIELD, NEARBY AREA					
Sec. 36, T. 2 S., R. 45 E.	31.61	4.7	0.30	8,015	Lignite A
Sec. 8, T. 3 S., R. 46 E. [2]	31.52	5.0	0.63	7,853	Lignite A
Average [3]	32.01	4.9	0.44	7,894	Lignite A

Footnotes:

1/ Information provided from Bull. 91, Montana Bureau of Mines and Geology, 1973.

2/ Composite sample.

3/ Average of three samples.

Thickness of Coalbeds

Within the Cook Mountain Study Area, the Knobloch Coalbed thins to the north from 59 feet to 46 feet thick. The average thicknesses of the Knobloch and Sawyer Coalbeds within the study area are 53 feet and 14 feet, respectively.

As noted previously, the Knobloch and Sawyer Coalbeds are known to split; however, only thin, isolated splits were encountered within the Knobloch Coalbed (none within the Sawyer) in drill holes within the Cook Mountain Study Area. Hence, all evaluations are based upon the assumption that the Knobloch and Sawyer Coalbeds do not split appreciably within the study area. Where splits were encountered (three drill holes), the total thickness of recoverable coal was assumed to be the entire thickness of the coal bearing interval minus the thickness of the split (usually less than 2 feet). Coal resources were evaluated on a per section basis. The average thickness of coal within each evaluated section is shown on Tables 4 through 19, Appendix C.

Thickness of Overburden

Coal resources were evaluated in five classes of overburden thicknesses (Tables 4 through 19); namely, 0 to 50 feet, 50 to 100 feet, 100 to 150 feet, 150 to 200 feet, and over 200 feet. Within the eight-section study area, overburden thicknesses over unclinkered Knobloch range from 10 feet to approximately 300 feet. Nearly 34 percent of the acres within this study area that contain Knobloch coal are covered by over 200 feet of overburden. The following percentages of total acres containing Knobloch coal are contained in the remaining overburden thickness classes: 2 percent in 0 to 50 feet; 9 percent in 50 to 100 feet; 21 percent in 100 to 150 feet; and 33 percent in 150 to 200 feet.

Within the eight-section study area, overburden thicknesses over unclinkered Sawyer range from 0 feet to approximately 140 feet. Nearly 85 percent of the total acres within the study area containing Sawyer coal are covered by 0 to 50 feet of overburden. Thirteen percent and two percent of the total area containing Sawyer are covered by 50 to 100 and 100 to 150 feet of overburden, respectively.

Tabulation of Coal Resources

Tables 4 through 19, Appendix C, summarize the estimated coal resources of the Cook Mountain Study Area. These tables show the coal resources, overburden and interburden volumes, overburden ratios, and tons per acre for each of the study area sections. As an indication of the degree of geologic assurance of the resource estimates, coal resources are classified as measured, indicated and inferred according to the following:

Measured coal resource is that coal which is located within an area bounded by a 1/4-mile radius from a point of observation.

Indicated coal resource is that coal within an area located by boundaries greater than 1/4-mile radius and less than 3/4-mile radius to a specific point of observation.

Inferred coal resource is the coal which lies more than 3/4 of a mile from any point of observation.

Tables 20 and 21 present a summary of the total measured, indicated and inferred coal resources within each section for the Knobloch and Sawyer Coalbeds, respectively.

Summary of Coal Resources

The estimated total resources presented in this report are original resources; that is, resources in the ground before the beginning of mining operations.

The total estimated original resources in the Cook Mountain Study Area are 367,170,000 tons. The Knobloch subbituminous C Coalbed contains 342,730,000 tons of coal resources, of which 138,410,000 tons are measured, 189,920,000 tons are indicated and 14,400,000 tons are inferred.

The Sawyer Coalbed, which is classified as lignite A contains 24,440,000 tons of coal resources, of which 8,950,000 tons are measured, 15,190,000 tons are indicated and 300,000 tons are inferred.

The weighted average stripping ratios for the Knobloch and Sawyer Coalbeds within the study area are 3.08 and 2.26, respectively, as shown on Tables 22 and 23.

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA

MEASURED, INDICATED, AND INFERRED COAL RESERVES OF THE
KNOBLOCH COALBED
(IN MILLIONS OF TONS)

LOCATION	MEASURED	INDICATED	INFERRED	SECTION TOTAL
T. 2 S., R. 44 E., Sec. 24	5.74	5.50	0.00	11.24
T. 2 S., R. 45 E. Sec. 18	11.20	29.87	12.27	53.34
S½ Sec. 29	8.16	21.75	0.30	30.21
Sec. 30	19.48	39.57	1.83	60.88
Sec. 32	39.95	23.45	0.00	63.40
T. 3 S., R. 45 E., W½ Sec. 4	12.36	19.34	0.00	31.70
Sec. 6	4.11	27.52	0.00	31.63
Sec. 8	37.41	22.92	0.00	60.33
STUDY AREA TOTAL	138.41	189.92	14.40	342.73

Table 20

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA

MEASURED, INDICATED, AND INFERRED COAL RESERVES OF THE
SAWYER COALBED
(IN MILLIONS OF TONS)

LOCATION	MEASURED	INDICATED	INFERRED	SECTION TOTAL
T. 2 S., R. 44 E., Sec. 24	0.00	0.00	0.00	0.00
T. 2 S., R. 45 E., Sec. 18	0.00	0.00	0.24	0.24
S½ Sec. 29	1.34	5.01	0.06	6.41
Sec. 30	0.96	2.22	0.00	3.18
Sec. 32	4.79	4.24	0.00	9.03
T. 3 S., R. 45 E., W½ Sec. 4	1.63	3.17	0.00	4.80
Sec. 6	0.00	0.00	0.00	0.00
Sec. 8	0.23	0.55	0.00	0.78
STUDY AREA TOTAL	8.95	15.19	0.30	24.44

Table 21

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA

WEIGHTED AVERAGE OVERBURDEN AND INTERBURDEN
STRIPPING RATIO OF THE KNOBLOCH COALBED 1/

LOCATION	STRIPPING RATIO	ACRES
T. 2 S., R. 44 E., Sec. 24	2.63	130.7
T. 2 S., R. 45 E., Sec. 18	2.51	650.9
S½ Sec. 29	5.29	320.0
Sec. 30	2.49	655.0
Sec. 32	3.53	639.5
T. 3 S., R. 45 E., W½ Sec. 4	3.51	321.0
Sec. 6	2.50	316.3
Sec. 8	2.85	625.3
AVERAGE 2/	3.08	TOTAL 3658.7

1/ Assumes younger coalbeds are wasted

2/ Average shown is a weighted average based on the number of acres per section containing Knobloch Coal.

Table 22

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA

WEIGHTED AVERAGE OVERBURDEN STRIPPING RATIO OF THE
SAWYER COALBED 1/

LOCATION	STRIPPING RATIO	ACRES
T. 2 S., R. 44 E., Sec. 24	---	0
T. 2 S., R. 45 E., Sec. 18	3.09	9
S½ Sec. 29	2.66	258.4
Sec. 30	2.28	128.4
Sec. 32	1.61	339.8
T. 3 S., R. 45 E., W½ Sec. 4	3.05	193.3
Sec. 6	---	0
Sec. 8	0.73	29.4
AVERAGE 2/	2.26	TOTAL 958.3

1/ Assumes younger coalbeds are wasted

2/ Average shown is a weighted average based on the number of acres per section containing Sawyer Coal.

Table 23

SOIL AND OVERBURDEN

Principal Soil Bodies

Soils of the Cook Mountain Study Area can be grouped into two major categories based on their parent material, mode of development, and landform position. These are: (1) Residual soils developing from sandstone, siltstone, shale, or baked rock (clinker) which occupy ridges, tabular divides, and moderate to steep upland slopes, and (2) Alluvial/Colluvial soils forming in mixed deposits on fans, footslopes, terraces, and bottomlands. The residual soils occur over approximately 80 percent of the study area; the alluvial/colluvial soils comprise the remaining 20 percent.

Residual Soils

The residual soils occur on the dissected, sedimentary uplands of the study area. The parent materials of these soils are interbedded sandstone, siltstone, shale, and baked rock belonging to the Tongue River Member of the Fort Union Formation.

In general, these soils are shallow to moderately deep, averaging about 20 inches to the underlying parent strata. Textures range from moderately coarse to fine, depending on the nature of the parent material.

Owing to the variability of the parent materials, the physical and chemical properties of these soils differ widely. For example, the residual soils developing from sandstone are medium to moderately coarse textured, nonsaline, nonsodic, and have moderate to moderately rapid permeabilities (see Table 24, Appendix D). In contrast, the residual soils forming from shale are moderately to strongly saline and have slow to very slow permeabilities (see Table 25, Appendix D). Locally, these soils are also moderately to strongly sodic.

Native vegetation on the residual soils also varies widely, with big sagebrush and short grasses dominating the moderately fine and fine-textured soils forming from shale and Ponderosa pine and mid grasses occupying the medium to moderately coarse soils developing from sandstone.

As a source of revegetative material, these soils are fair to good in quality, but limited in quantity due to their shallow nature. Also, stripping operations may be difficult due to steep slopes, vegetative cover (trees), and bedrock outcrops, which are common on crests and along steep slopes.

Alluvial/Colluvial Soils

The alluvial/colluvial soils occur on upland fans, footslopes, and terraces, and in bottomland positions along Cook Creek and Double E Coulee. These soils are moderately deep (fans, footslopes) to deep (high terraces, bottomlands) over stream-laid deposits or slope wash derived locally from sandstone, siltstone, shale, and baked rock of the Tongue River Member, Fort Union Formation.

Soil textures are predominantly medium, but vary locally with the nature of the deposits. In most cases, these soils are nonsaline, nonsodic, and slowly to moderately permeable. Locally, however, the subsurface horizons are moderately saline, moderately to strongly sodic, and/or very slowly permeable. These

unfavorable properties are inherited primarily from saline shales, which are exposed at the surface in numerous locations within the study area.

Native vegetation on these soils consists of mid and short grasses, numerous forbs, and scattered shrubs and deciduous trees along the main tributary drainages.

These soils represent an abundant supply of good quality revegetative material. Local subsurface horizons influenced by salinity, sodicity, or high clay percentage will require special placement below the plant rooting zone in reconstructed profiles. Stripping operations should not be difficult, with the exception of tree/brush removal in bottomland areas.

Point site profiles typical of this soil category are described in Tables 26 through 30, Appendix D.

Land Suitability Classification

A semidetailed land suitability classification of the Cook Mountain Study Area was made to evaluate and characterize the soil and overburden to 10 feet in depth as a source of material for resurfacing and revegetating the area if it is surface-mined. This classification provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling the usable material, and other factors which affect the land's suitability for reclamation and revegetation.

Land suitability specifications, shown on Table 31, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined lands. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes in the Bureau of Reclamation land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, percent stones (>3 inches), erodibility, and available water-holding capacity. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included hard bedrock exposures (outcrops) and steep, rough, or complex slopes.

Class 1 lands provide the most desirable and plentiful source of material for revegetation. An abundant supply of highly suitable material, which is easily stripped and stockpiled, will be available from this land class. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 lands can provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material on Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Land in this class is marginally suitable for revegetation but, through utilization of good stripping and stockpiling procedures, the requirements for planting media can generally be met. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from Class 1 or 2 lands or modify the material available for revegetation through leaching, addition of chemical amendments, etc.

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Soil/Overburden for Revegetation of Surfaced-Mined Areas
BLM/BR Cooperative Program - EMRIA
Cook Mountain Study Area

United States
Dept. of the Interior
Bureau of Reclamation
June 1980

Soil and Overburden Characteristics	Symbols Basic Subclass	Symbols Information and Deficiencies	Class 1	Class 2	Class 3
SOILS AND/OR OVERBURDEN	s				
Textures			Fine sandy loams to clay loams	Sandy loam to silty clay loams	Loamy sand to clay
Coarse		v		Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly.	Loamy sand in sufficient quantity to moderately reduce productivity, moisture retention, and may increase erosiveness moderately.
Fine		h		Profile should have sufficient material for topdressing, clayey type materials that are slowly permeable should be placed below 6" in the reconstructed profile.	Profile should have sufficient material for topdressing, placement of clay in reconstructed profile-permeable: 10" plus; slowly permeable: 30" plus.
Depth		d	>36" of soil/overburden that is suitable for plant media.	>18" of soil/overburden that is suitable for plant media.	>10" of soil/overburden that is suitable for plant media.
Sodicity		a	SAR not to exceed 9.0 in fine textured materials but may be 20.0 with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum.		
Salinity (ECe x 10^3)		s	Less than 4	Less than 8 but should have 10" of material of less than 4 for surface.	Less than 12 but should have 10" of material of less than 4 for surface.
Available Water Holding Capacity		q	>1.5"/foot of soil	>1.0"/foot of soil	>0.75"/foot of soil.
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate.	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion.
Cobbly, Stony, Flaggy, or Clinkers		x	Less than 5% by volume.	Less than 10% by volume.	Less than 20% by volume.
Weatherability 1/			Will break down readily upon exposure to the weather.	May require short period to break down upon exposure.	May require extended period to break down.
Erodibility			Susceptible to slight erosion.	Susceptible to moderate erosion.	Susceptible to severe erosion but can be controlled with proper management and selective placement.
TOPOGRAPHY 2/	t				
Slope		g	Permissible surface gradient 0 to 12% with smooth slopes.	Permissible surface gradient 0-20%	Permissible surface gradient 0-35%.
Indurated Surface Sandstone or Baked Rock		r	None	1 to 5% of area.	5 to 20% of area.
Cover		c	Not applicable		
DRAINAGE	d		Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification.		
Class 6			Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient soil or overburden of suitable quality at or near the surface; (2) topography which prevents stripping, including excessive slopes; (3) rocklands with large amounts of indurated surface sandstone or baked rock; (4) toxic material (soil or overburden), at or near the surface. Reclamation of Class 6 lands will require that suitable plant growth material be borrowed from adjacent lands that have a surplus of good quality planting media or from suitable overburden strata. In certain cases, treatment or modification of the available material may increase its revegetative potential to an acceptable level.		

1/ Applicable only to overburden material.
2/ Not applicable to overburden material.

Table 32 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability classification was accomplished using Bureau of Reclamation methods and procedures. Field mapping was done on aerial photographs with a scale of 1:12,000. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used in the field to supplement the slope data on the topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are typically located in transitional areas between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the soil/overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil/overburden material for hydraulic conductivity and available waterholding capacity in relation to the reconstructed profile was a major consideration in the field evaluation. Using these basic evaluations, along with observations of other land features such as exposed hard bedrock, slope, and landscape complexity, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 27 through 29, Appendix D.

A laboratory was used in connection with the land suitability classification and screenable tests were performed on all samples. These tests included disturbed hydraulic conductivity, salinity, pH, 15-bar moisture retention, and settling volume. More detailed analyses were then made as required. Exhibit 1, Appendix D describes the screenable testing procedures used in the laboratory.

Complete analyses, including selected trace element determinations, were performed on all samples from Point Site profiles representative of the major land class categories. The analyses listed in Exhibit 2, Appendix D, were performed as needed for proper soil and overburden evaluation.

Results of Land Suitability Classification

The results of the land suitability classification are presented on semidetailed drawings, Plates 27 through 29, Appendix D, which show the areal distribution of the various land classes, soil/overburden deficiencies, topographic deficiencies, profile notes of soil/overburden borings, and the results of selected laboratory analyses. This information is also summarized on Plates 30 through 35, Appendix D.

Plates 30 through 32, Appendix D, describe the location and depth of topsoiling material that is suitable for surface placement in reconstructed profiles. Plates 33 through 35, Appendix D, indicate the location and quantity of material that is suitable for subsurface replacement below the primary plant rooting zone.

Table 33 lists the acreage of each land class occurring in the study area. The results in this table indicate that 58.3 percent of the land in the Cook Mountain Study Area contains an adequate or surplus supply of suitable soil and/or overburden to restore the disturbed area to a condition capable of supporting the present land uses. This includes Class 1, 2, and 3 lands. The remaining 41.7 percent of the study area, designated as Class 6, consists primarily of steep, dissected uplands dominated by shallow soils. Reclamation of these lands to their present topographic condition would appear impractical and uneconomical. If these lands are disturbed by surface mining, the reclaimed landscape would undoubtedly be restored to a more gently rolling condition. Surplus soil or good quality overburden could be borrowed from Class 1 or 2 lands to provide a deeper root zone and enhance permanent revegetation on these lands.

This land suitability classification provides baseline data for assessing reclamation potential. It does not, however, provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations, supported by laboratory data, will be necessary to more accurately determine the quantity, quality, and location of available material to be stripped and stockpiled for use as a revegetative medium.

Soil and Overburden Suitability for Revegetation

Soil Mantle Suitability

The alluvial/colluvial soils, which cover about 20 percent of this study area, will provide an abundant source of material for revegetation. The combined thickness of the A and B horizons of these soils ranges from 12 to 24 inches. This material, which is nonsaline, nonsodic, and moderately permeable, will be highly desirable for surface replacement since most of the organic matter and available nutrients are contained in these horizons.

Since the A horizon is typically only 2 to 4 inches thick (except for Ap horizons - 6 to 8 inches), selective stripping of this horizon from the B horizon appears impractical. However, mixing of these horizons should not appreciably change the overall quality of the material. In most cases, the C horizons of these soils will provide 6 to 8 (or more) feet of fair to good quality subsurface material. In local areas where the C horizons contain high levels of soluble salts, exchangeable sodium, clay, or coarse sands, every effort should be made to selectively place these materials at least 3 to 4 feet below the surface in reconstructed profiles.

Since slopes on which these soils occur are gentle to moderate, stripping conditions appear favorable (except for tree/brush clearing along Cook Coulee and Double E Coulee drainages).

The residual soils, though they cover about 80 percent of the study area, represent a limited source of revegetative material due to their shallow nature and the "broken" landscape they occupy.

Table 32 Description of Land Classes

Class Subclass	% of Area	Soil/Overburden Characteristics	Land Features	Management Requirements
1	25.7	Land in this class has an average minimum depth of 36 inches of good or high quality soil/overburden that is suitable for plant media. Usually this material is dark colored soil that has formed in deep alluvial, colluvial, and residual deposits. Medium texture is most common. Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. Below 18 inches the material is moderately to strongly calcareous. These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsoil placement. This material, when borrowed, will enhance productivity of other tracts.	The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and undulating uplands. Most of this land produces small grains, hay, or native range. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.	These materials will be slightly susceptible to wind and water erosion, but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2s	10.15	Land in this class has an average minimum depth of 18 inches of fair and good quality soil/overburden that is suitable for plant media. Usually this material is largely medium and moderately coarse textured soil that has formed in deep colluvial and alluvial deposits and in moderately deep residual material. Textures range from sandy loams to clay loams. Good quality overburden material may be considered as part of the 18" requirement. Below 18 inches the overburden is usually calcareous. Limitations other than depth include: clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and/or sodic. Soil aggregates of these materials have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.	The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stockpiling; also, selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.	Selection of suitable material for use at or near the surface will require a review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline permeable material for the subsoil and substratum. Selective stripping and stockpiling to isolate subsurface material, followed by selective placement, is necessary for the best use of available material in this land class. With proper selection and placement, reclamation should not be difficult, and average management should enhance successful permanent revegetation.
2t	0.05	Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Usually this material is dark colored soil that has formed in deep alluvial, colluvial, and residual deposits. Medium texture is most common. Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. Below 18 inches the material is moderately to strongly calcareous. These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.	The surface relief comprises strongly sloping side slopes. Selective stripping may be difficult.	These soils will be slightly susceptible to wind and water erosion, but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2st	1.8	The general description of soil/overburden characteristics of Class 2s applies to this class. The most common limitations are quantity of usable material, slow permeability, and moderate salinity and/or sodicity.	The surface relief comprises moderately sloping to rolling foot slopes and smooth, steep side slopes. Selective stripping may be difficult and some mixing of surface and subsoil material will occur.	A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s lands applies to this class also.

Table 32 Description of Land Classes (cont'd)

Class Subclass	% of Area	Soil/Overburden Characteristics	Land Features	Management Requirements
3s	14.2	Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitable for plant media. Usually this material is largely medium to moderately fine textured soil that has formed in alluvial, colluvial, and residual deposits. The principal limiting factor is the quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contain moderate to high amounts of sodium and large amounts of gypsum. Laboratory tests indicated fair to poor permeability. Land in this class retains a large quantity of water for plant use. The infiltration rate and internal water movement are moderately slow.	The surface relief comprises nearly level alluvial terraces and adjacent foot slopes. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Some tracts produce mixed grass hay.	For best use of the soil/overburden in this class, the surface material must be stripped and stockpiled, and the subsoil and substratum should be placed with the spoil material. Pitting or gouging basins will retard erosion and help promote leaching of soluble salts below the primary root zone. Mulches can also be used to reduce erosion. These measures can increase the effective leaching of soluble salts and increase production capability. Successful permanent revegetation can be accomplished, but above average planning and management will be required.
3t	0.0	Land in this class has an average of 36 inches of good and high quality soil/overburden that is suitable for plant media. Usually this material is dark colored soil that has formed in deep alluvial, colluvial, and residual material. Medium textures are most common. Surface material in this class is nonsaline, non-sodic, and moderately high in organic matter. There is no indication of toxic contaminants. The subsurface material below 18 inches is moderately to strongly calcareous. Soil aggregates of these soils have moderate to good stability, allowing water to enter the surface layers readily. Internal permeability is moderate to moderately slow and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant root zone. These lands are a good source of quality soil/overburden that is suitable for topdressing or subsurface placement. This material, when borrowed, will enhance the productivity of other tracts.	The surface relief comprises moderately steep, complex side slopes and crests. Selective stripping will be difficult.	These soils will be moderately susceptible to wind and water erosion, but management practices such as vegetative mulching, mechanical roughing, or contour planting should provide adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
3st	9.4	Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitable for plant media. Usually this material consists of moderately coarse or moderately fine textured residual soil or weathered shale or sandstone parent material. The major limitation is quantity of nonsaline and nonsodic material. There is adequate suitable material for revegetation for rangeland. Extensive borrowing of material would be required for profiles suitable for dryland farming. Locally, the overburden material is permeable and the soluble salts can be leached. Some clay-rich and sodium affected layers will most likely be included in the stockpiled material, but this should be held to a minimum.	The surface relief of land in this class is characterized by strongly sloping foot slopes, moderately steep side slopes, and crests in hilly upland areas. Moderately steep slopes will make selective stripping difficult. Native mid and short grasses are the dominant species. This land is used for range.	Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed.
6s	3.1	Land in this class has less than 10 inches average depth of fair and good quality soil/overburden that is suitable for plant media. These materials are typically sandy or clay-rich below the surface layer and often highly saline and/or sodium affected. One or a combination of the above factors make these materials unsuitable for plant media. Some small tracts with good quality soil/overburden occur in this class as inclusions.	The surface relief in this class comprises nearly level to very gently sloping old alluvial terraces and residual foot slopes and benches. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses are the dominant range species.	A careful review of the data and field checking to locate the small inclusions of better soil/overburden is warrented. This, combined with selective stripping, can do much to reduce the amount of revegetation material that must be borrowed or modified. Temporary irrigation, pitting, and gouging basins to increase leaching may adequately modify some material. However, borrowing from nearby deep, good quality lands will probably be the most economical method of permanent revegetation.

Table 32 Description of Land Classes (cont'd)

Class Subclass	% of Area	Soil/Overburden Characteristics	Land Features	Management Requirements
6t	0.1	Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Soils in this class have formed in deep alluvial, colluvial, or residual material. They are usually dark colored and moderately high in organic matter. Textures are commonly medium and moderately fine. These materials are nonsaline, nonsodic, and moderately to strongly calcareous below a depth of 18 inches. Aggregate stability is moderate to good in these materials, and water readily infiltrates the surface. Internal permeability is moderate to moderately slow, and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant zone. Where accessible, the soils/overburden from this land class will provide good quality material suitable for top-dressing or subsurface placement.	The surface relief comprises areas of complex, narrow bottom lands and dissected upland areas with steep side slopes below ridge crests. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping. Active erosion may expose sandstone, shale, or baked rock in up to 25 percent of any designated area. Ponderosa pine/Little bluestem dominate upland sandy sites; Big sagebrush/forbs occur on shallow upland sites overlying shale; deciduous trees/brush are common in narrow drainage bottoms. This land class is used for range.	These soils will be highly susceptible to wind and water erosion. Management practices such as vegetative mulching, mechanical roughing, or contour planting will help retard soil erosion. For maximum use of soil in this land class, the upper 6 to 24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
6st	41.7	Land in this class has less than 10 inches average depth of fair and good quality soil/overburden that is suitable for plant media. Soil materials are typically shallow over weathered shale. Sandstone and shale outcrops are common. The underlying overburden is highly variable in physical and chemical properties. It may be highly saline, highly sodic, slowly permeable, or fine textured (clay-rich). These limitations occur singly or in combination in most areas delineated as Class 6st. Small inclusions of deeper soils and permeable, nonsaline, and nonsodic overburden material are common within these delineated areas.	The surface relief in this class comprises steep side slopes below ridge crests. Active erosion may expose sandstone or shale in up to 25 percent of any tract designated as Class 6st. The dendritic drainage pattern creates complex slopes that prevent uniform selective stripping. Ponderosa pine/Little bluestem dominate upland sandy sites; Big sagebrush/forbs occur on shallow upland sites overlying shale; deciduous trees/brush are common in narrow drainage bottoms. This land class is used for range.	Tracts with deeper soils and suitable overburden material, though small, should be selectively stripped. Mechanical roughing of the surface will increase infiltration and enhance leaching of soluble salts. Vegetative mulching, contour planting, and the use of stabilizing structures will aid in reducing erosion. Borrow material will be required for successful permanent revegetation. The postmining soil profile and vegetative cover will likely be an improvement over present conditions.

Table 33 - Results of the Land Suitability Classification
Cook Mountain Study Area, Montana

Location	Land Classes-Acreage										Total
T.2S.,R.44E.	1	2s	2t	2st	3s	3t	3st	6s	6t		
Section 24	42.5	143.5	2.5	0.0	23.9	0.0	14.9	0.0	0.0	412.7	640.0
T.2S.,R.45E.											
Section 18	83.8	48.7	0.0	0.0	59.4	0.0	123.5	10.3	0.0	325.2	650.9
Section 29	162.6	30.0	0.0	17.0	26.4	0.0	53.0	0.0	0.0	31.0	320.0
Section 30	134.8	52.6	0.0	46.4	56.6	0.0	82.9	36.2	0.0	245.5	655.0
Section 32	175.8	85.6	0.0	9.4	116.9	0.0	82.5	12.6	0.0	156.7	639.5
T.3S.,R.45E.											
Section 4	64.6	52.0	0.0	9.2	77.4	0.0	3.3	20.4	0.0	94.1	321.0
Section 6	241.9	19.5	0.0	0.0	152.2	0.0	14.3	3.6	4.9	247.0	683.4
Section 8	126.2	29.8	0.0	0.0	130.8	0.0	54.3	57.4	0.0	241.5	640.0
Total Acres	1032.2	461.7	2.5	82.0	643.6	0.0	428.7	140.5	4.9	1753.7	4549.8
Percent of Study Area	22.7	10.15	0.05	1.8	14.2	0.0	9.4	3.1	0.1	38.5	100.0

Many of the shallow soils developing from shale have A-C profiles. The A horizon (2 to 6 inches thick) is usually moderately fine textured, nonsaline, nonsodic, and slowly permeable. This material, though favorable for surface replacement, may be difficult to strip due to topographic limitations (steep slopes, outcrops). The C horizons and substratum are typically fine textured and moderately to strongly saline. Locally, they are also sodic. As such, this material is undesirable as a revegetative medium; therefore, replacement should be at least 3 to 4 feet below the surface.

The residual soils forming from sandstone could provide about 12 to 18 inches of good quality topsoiling material (combined A and B horizons). However, steep slopes and numerous outcroppings may severely limit stripping operations. The C horizons and weathered substratum, though nonsaline and nonsodic, are suitable only for subsurface replacement due to their coarse textures, low moisture-holding capacity, and susceptibility to erosion.

Plates 30 through 35, Appendix D, are maps showing the location and quantity of available topsoil and subsurface material in the Cook Mountain Study Area. This information was projected from the land classification maps, Plates 27 through 29, Appendix D.

Overburden Suitability

Overburden samples from Intrasearch, Inc., drill holes 24530-2C and 3458-3C (logs shown on Plates 14 through 24, Appendix B) were evaluated as to their suitability for use as supplemental plant media.

Complete laboratory analyses, including selected trace element determinations, were performed on the samples by Northern Testing Laboratories, Billings, Montana (see Tables 34 through 36, Appendix D). The results of these analyses provided the data base for this suitability evaluation.

Suitability criteria developed by the Bureau of Reclamation (Table 37, Appendix D) were applied to the laboratory data in order to place the overburden materials into one of three categories: Suitable, Limited Suitability, or Unsuitable.

Table 38, Appendix D, presents the results of the overburden suitability evaluation. Overall, 44.9 percent of the overburden materials lying above and directly below (interburden) the Knobloch Coalbed in drill hole 24530-2C were determined to be suitable for use as a supplemental plant medium; 42.6 percent were of limited suitability; and 12.5 percent were unsuitable. In drill hole 3458-3C, 15.1 percent of the overburden/interburden materials were rated suitable; 55.8 percent were of limited suitability; and 29.1 percent were unsuitable.

In drill hole 24530-2C, high percentages of exchangeable sodium and/or clay were the major limiting factors causing materials to be placed in the limited suitability or unsuitable categories. In addition, a high level of lead (56.0 ppm) was found in the deepest sample tested, a hardened shale from 177.6 - 178.0 feet.

High levels of exchangeable sodium, clay or sand (relates to erosion potential), and trace elements were the major limiting factors for samples obtained from drill hole 3458-3C. Salinity was low in all but three of the samples, in which it was moderate. A high concentration of nickel (6.76 ppm) was found in a

carbonaceous shale sample from 179.8 - 185.0 feet; and excessive lead (25.0 ppm) occurred in the deepest sample, a shale from 241.8 - 243.0 feet. A limited correlation appears evident between the lead levels in this sample and the hardened shale sample from drill hole 24530-2C, as both samples were from similar strata immediately underlying the Knobloch Coalbed.

The samples from both drill holes which were rated suitable consisted primarily of fine-grained sandstones or sandy shales which were nonsaline, nonsodic, and medium textured.

This suitability evaluation provides a general overview of overburden suitability for revegetation in the Cook Mountain Study Area. It should be recognized, however, that this evaluation was made on a site - specific basis; therefore, the results apply only to the specific location where each hole was drilled. No attempt should be made to project the results between the holes or over the entire study area, as wide variations in overburden type and quality would preclude the accuracy of these projections.

GREENHOUSE EVALUATION OF SOIL AND OVERBURDEN MATERIALS

Introduction

The data in this section was provided by E&A Environmental Consultants, Inc., Sharon, Massachusetts, under Bureau of Reclamation Contract Number 1-07-DV-00124.

This report presents the greenhouse data for 37 soil and overburden samples obtained from the Cook Mountain Study Area in southeastern Montana. These samples were procured from 7 USBR Point Site soil profiles described in Tables 24 through 30, Appendix D.

The soil or overburden material was placed in 10" plastic pots. Each pot contained 2800 grams of soil. Three replicates of each soil was seeded to Barley var. Steptoe. This variety was obtained from the USDA High Plains Grassland Research Station in Cheyenne, Wyoming. Prior to seeding, the soils received Nitrogen and Phosphorus fertilizer at a rate of 60 lbs/acre N as ammonium nitrate and 80 lbs/acre of P as triple phosphate.

On July 16, 1981, the pots were seeded with 10 seeds per pot. However, due to poor germination, the pots were reseeded with 35 seeds per pot on August 2, 1981. The poor germination appeared to have resulted from the poor surface soil conditions and surface soil moisture. Covering the pots and maintaning humid conditions during the second seeding resulted in germination in all pots.

In order to avoid leaching of salts, the pots were watered 3 times per week with 100 ml water at each time.

By mid-August, all the plants showed a characeristic nitrogen deficiency and were fertilized with a soluble 15-15-15 fertilizer. There was an immediate noticeable greening and excellent growth thereafter.

Preplant Analysis of Soil and Overburden

Table 39 shows the preplant analyses data for the 37 samples. Since Potassium and Phosphorus were added as fertilizers along with Nitrogen, these parameters are essentially meaningless. However, it should be noted that plant-available P was very low and most of the available K was low for most of the samples tested.

Manganese (Mn), Zinc (Zn), Iron (Fe), and Copper (Cu) are usually not toxic to plants in neutral or alkaline soils. With the exception of three samples (T1, T27, T32), which had a pH of 6.7, all of the samples had a pH above 7.0. Plants grown on alkaline soils can be deficient in these elements. In general, total Zn in soils ranges from 10 to 300 ppm; Mn ranges from 100 to 4000 ppm; Cu ranges from 2 to 100 ppm (Underwood, 1971).

Total Boron (B) in the 37 samples ranged from 4.7 to 12 ppm; Arsenic (As) ranged from 7.1 to 26.9 ppm. Normal ranges in soils are 2 to 100 ppm for Boron and .1 to 40 ppm, with an average of 6ppm, for Arsenic. Molybdenum (Mo) was not detected in any of the samples.

Sodium Adsorption Ratio (SAR) values ranged from 0.1 to 18.4. SAR values below 10 have a low sodium (alkaki) hazard. Of the 37 samples, 12 had SAR values

exceeding 10. An important consideration is the effect of excessive sodium on permeability. Soil or overburden materials containing moderate or high amounts of clay may become highly dispersed and virtually impermeable at SAR's exceeding 10.

Electrical conductivity (ECe x 10^3) of the soils ranged from 0.26 to 14.00 mmhos/cm. Most crops will tolerate EC values up to 4.00. EC values above 8.00 are tolerated by very few crops as a deleterious effect on germination occurs. Many of the grasses and barley will show a 50 percent yield reduction when EC = 16 to 18. Of the samples tested in this study, eight had EC values greater than 8.00. Samples T8, T9, T26, and T34 had EC values above 10.00.

Plant Analyses Data

Plant Growth Aspects

Table 40 shows the yield of barley for the 37 samples tested. A control sample (Ap horizon, Merrimac sandy loam) was included for comparison. This control had the highest yield. The relationship of dry weight versus depth is shown in Figures 1 through 8, Appendix E. Figure 1 shows all of the 37 samples and their relation to plant growth. Samples T27, T28, and T30 produced the highest dry matter. Samples T27 through 31, obtained from Point Site number 8 (Table 24, Appendix D) produced the highest yield. The analysis of variance (AOV) of fresh weight and dry weight as related to the soils and their respective depths is shown in Table 41, Appendix E. Significant differences in dry weight were found between depths in Point Sites 13 and 12. (Tables 26 and 28, respectively, Appendix D); and in the fresh weights in Point Site number 13, 9, and 12 (Tables 26, 27, and 28, respectively, Appendix D).

To test the differences in plant yield due to variability in depth, a Duncan Multiple Range Test was conducted. The results are shown in Tables 42 and 43, Appendix E. Significant differences for depths and dry weight of plants were found in samples from Point Sites 13, 9, 12, and 9 (Tables 26, 27, 28, and 30, respectively, Appendix D). The major difference occurred between the surface layer and the remaining layers. For Point Site 9 (Table 30, Appendix D), growth in samples T1, T2, and T5 was significantly better than in T3 and T4. For Point Sites 9 and 12 (Tables 27 and 28, respectively, Appendix D), the surface layer produced a significant difference in plant yield. In Point Site 13 (Table 26, Appendix D), the two uppermost layers produced higher yields. Similar results were found with fresh weights.

Table 44, Appendix E, describes some of the observations recorded during midgrowth of the plants. The most important observation was the fact that some germination occurred in all of the samples. With the exception of samples T26, T34, and T36, germination ranged from fair to excellent. By the end of the 60 days, the plants had produced heads in 85 percent of the pots.

Table 45, Appendix E, represents the top/root ratio for several selected samples. In general, most samples had a lower ratio than the control. Sample T31 surprisingly had a higher ratio. The very low ratio implies that some factor(s) may have been toxic to plant growth.

Table 46, Appendix E, presents the interrelationships between the preplant analysis data and plant growth as determined with the correlation coefficient (R).

Preplant Analysis of Soil/Overburden Material

Sample No.	Depth	Total Sand	Silt	Clay	CEC
	Inches	%	%	%	%
T-1	0-13	45.2	49.8	5.0	22.6
T-2	13-39	44.6	51.4	4.0	17.0
T-3	39-60	44.3	50.7	5.0	14.9
T-4	60-96	36.0	60.1	3.9	10.2
T-5	96-120	50.6	33.9	15.5	14.6
T-6	0-8	23.1	46.9	30.0	36.5
T-7	8-17	28.7	42.8	28.5	23.3
T-8	17-36	24.5	47.6	27.9	17.0
T-9	36-60	30.6	43.7	25.7	15.6
T-10	60-89	26.5	50.9	22.6	13.1
T-11	84-102	25.7	47.0	27.3	18.8
T-12	102-120	29.0	47.0	24.0	26.3
T-13	0-17	34.1	44.0	21.9	19.0
T-14	17-32	32.0	45.6	22.4	14.0
T-15	32-54	38.7	44.1	17.2	10.4
T-16	54-78	37.1	46.8	16.1	11.1
T-17	78-102	48.1	36.0	15.9	12.1
T-18	102-120	46.9	39.7	13.9	10.4
T-19	0-17	43.1	40.4	16.5	16.9
T-20	17-30	48.3	33.9	17.8	12.2
T-21	30-60	39.1	39.8	21.1	9.9
T-22	60-84	7.3	61.8	30.9	13.9
T-23	84-102	22.8	49.2	28.0	18.7
T-24	0-4	2.0	54.6	43.4	15.6
T-25	4-14	4.8	56.2	39.0	13.5
T-26	14-48	1.5	61.3	37.2	9.7
T-27	0-5	70.7	29.3	7.3	9.8
T-28	5-13	61.6	37.2	1.2	9.5
T-29	13-34	69.1	20.4	10.5	4.6
T-30	34-72	70.1	22.8	7.1	4.3
T-31	72-120	63.7	30.1	6.2	9.9
T-32	0-8	28.0	59.4	12.6	13.2
T-33	8-27	22.7	56.0	21.3	10.1
T-34	27-48	41.6	42.9	15.5	8.0
T-35	48-76	24.6	53.6	21.8	8.9
T-36	76-94	42.8	39.8	17.4	7.9
T-37	94-120	38.4	50.8	10.8	6.9

Preplant Analysis of Soil/Overburden Material (cont'd)

Sample No.	Plant Available			
	Zn	Fe	Cu	Mn
	ppm	ppm	ppm	ppm
T-1	<0.1	0.2	<0.1	2.1
T-2	<0.1	<0.1	<0.1	2.8
T-3	<0.1	2.7	<0.1	23.0
T-4	<0.1	7.2	<0.1	30.0
T-5	<0.1	9.6	<0.1	33.0
T-6	<0.1	0.6	<0.1	2.6
T-7	<0.1	0.9	<0.1	2.3
T-8	<0.1	0.6	<0.1	7.1
T-9	<0.1	2.4	<0.1	24.0
T-10	<0.1	2.2	<0.1	27.0
T-11	<0.1	3.6	<0.1	28.0
T-12	<0.1	6.5	<0.1	31.0
T-13	<0.1	0.8	<0.1	2.5
T-14	<0.1	0.4	<0.1	1.3
T-15	<0.1	2.8	<0.1	18.0
T-16	<0.1	6.3	<0.1	29.0
T-17	<0.1	4.8	<0.1	28.0
T-18	<0.1	10.0	<0.1	29.0
T-19	<0.1	0.2	<0.1	1.3
T-20	<0.1	0.6	<0.1	2.3
T-21	<0.1	0.2	<0.1	3.5
T-22	<0.1	0.2	<0.1	13.0
T-23	<0.1	0.5	<0.1	11.0
T-24	<0.1	1.3	0.3	17.0
T-25	<0.1	2.6	0.5	8.6
T-26	<0.1	5.2	0.4	26.0
T-27	<0.1	0.5	<0.1	0.9
T-28	<0.1	0.6	<0.1	1.7
T-29	<0.1	0.8	<0.1	1.1
T-30	<0.1	0.9	<0.1	6.4
T-31	<0.1	6.0	<0.1	14.0
T-32	<0.1	<0.1	<0.1	1.0
T-33	<0.1	1.1	<0.1	9.1
T-34	<0.1	4.5	<0.1	23.0
T-35	<0.1	2.0	<0.1	28.0
T-36	<0.1	10.0	<0.1	28.0
T-37	<0.1	18.0	<0.1	33.0

Preplant Analysis of Soil/Overburden Material (cont'd)

Sample No.	Saturation Extract		Plant Available	
	Ca	Mg	P	K
	me/l	me/l	ppm	ppm
T-1	3.1	2.1	<0.1	58
T-2	1.2	1.6	<0.1	11
T-3	0.4	2.5	<0.1	14
T-4	0.2	2.3	<0.1	26
T-5	0.3	1.9	<0.1	33
T-6	1.1	1.1	<0.1	47
T-7	1.0	2.0	<0.1	15
T-8	22.7	68.1	<0.1	34
T-9	5.0	42.2	<0.1	48
T-10	20.2	32.4	<0.1	63
T-11	6.2	19.6	<0.1	68
T-12	20.6	28.2	<0.1	58
T-13	0.8	2.3	<0.1	58
T-14	1.3	1.9	<0.1	6
T-15	0.4	2.0	<0.1	10
T-16	0.7	2.2	<0.1	19
T-17	0.9	5.6	<0.1	28
T-18	0.3	2.7	<0.1	29
T-19	5.5	3.2	<0.1	83
T-20	1.9	2.0	<0.1	14
T-21	0.5	1.8	<0.1	18
T-22	0.7	4.2	<0.1	42
T-23	1.7	10.2	<0.1	77
T-24	24.0	51.9	1.0	37
T-25	4.5	6.4	<0.1	52
T-26	21.1	107.2	<0.1	52
T-27	3.3	1.6	1.0	73
T-28	2.9	0.9	<0.1	29
T-29	1.8	0.7	<0.1	6
T-30	2.1	1.6	<0.1	2
T-31	0.6	1.8	<0.1	11
T-32	2.9	1.7	2.0	121
T-33	9.7	14.9	<0.1	77
T-34	3.0	22.9	<0.1	108
T-35	5.9	54.2	<0.1	147
T-36	2.8	25.8	<0.1	107
T-37	0.4	13.8	<0.1	84

Preplant Analysis of Soil/Overburden Material (cont'd)

Sample No.	SAR	pH(Paste)	Sat.%	EC
				mmhos/cm
T-1	0.1	6.9	38.5	0.60
T-2	0.2	7.9	39.3	0.34
T-3	0.5	8.2	35.0	0.36
T-4	1.5	8.4	34.3	0.44
T-5	3.1	8.4	33.2	0.58
T-6	4.3	7.8	44.0	0.82
T-7	11.8	8.2	62.1	1.90
T-8	16.1	8.1	51.8	14.00
T-9	17.9	8.1	50.2	10.00
T-10	13.6	8.1	45.9	9.50
T-11	17.2	7.8	52.7	8.00
T-12	11.9	7.8	49.1	8.00
T-13	0.2	7.4	23.8	0.56
T-14	0.3	8.0	39.5	0.36
T-15	3.9	8.4	36.3	0.70
T-16	11.3	8.5	31.7	1.10
T-17	10.4	8.6	33.5	2.50
T-18	11.9	8.6	32.1	1.90
T-19	0.1	7.0	42.0	0.94
T-20	2.1	8.0	34.5	0.46
T-21	3.7	8.4	37.0	0.62
T-22	9.3	8.4	46.1	2.00
T-23	9.9	8.3	45.3	3.60
T-24	1.9	7.8	55.5	6.00
T-25	0.6	7.6	44.5	1.20
T-26	6.8	8.3	54.9	12.00
T-27	0.1	6.7	34.4	0.68
T-28	0.1	7.4	28.8	0.46
T-29	2.5	7.9	31.8	0.26
T-30	0.1	8.1	30.1	0.42
T-31	0.2	8.6	35.0	0.26
T-32	0.1	6.7	50.1	0.53
T-33	4.9	7.9	40.9	3.80
T-34	9.8	8.4	29.5	6.50
T-35	17.3	8.5	42.2	12.00
T-36	18.4	8.6	35.0	8.10
T-37	16.6	8.4	26.5	5.60

Preplant Analysis of Soil/Overburden Material (cont'd)

Sample No.	Total Analysis		
	B	Mo	As
	ppm	ppm	ppm
T-1	8.3	0	11.0
T-2	7.6	0	8.3
T-3	7.4	0	7.4
T-4	7.8	0	10.0
T-5	8.9	0	9.9
T-6	10.3	0	19.0
T-7	11.5	0	14.4
T-8	10.3	0	21.6
T-9	10.9	0	18.1
T-10	10.4	0	13.9
T-11	10.7	0	11.9
T-12	11.2	0	11.0
T-13	9.7	0	21.1
T-14	8.9	0	12.9
T-15	9.1	0	7.1
T-16	9.1	0	10.5
T-17	9.0	0	12.1
T-18	10.2	0	10.0
T-19	10.7	0	19.8
T-20	10.3	0	15.1
T-21	8.3	0	10.5
T-22	10.4	0	11.6
T-23	10.5	0	13.6
T-24	12.0	0	26.9
T-25	9.6	0	26.1
T-26	8.3	0	12.9
T-27	6.0	0	10.6
T-28	6.0	0	12.6
T-29	5.6	0	11.6
T-30	5.5	0	8.7
T-31	4.7	0	11.7
T-32	8.8	0	16.6
T-33	9.1	0	12.3
T-34	7.7	0	10.7
T-35	11.7	0	16.0
T-36	9.1	0	12.8
T-37	10.7	0	13.7

Preplant Analysis - DTPA - Extractable Ni, Cd, and Pb*

Sample	Element (ppm)		
	Ni	Cd	Pb
T-1	1.0	0.03	0.45
T-1P	1.0	0.02	0.29
T-2	0.8	0.03	0.31
T-2P	0.7	0.01	0.28
T-3	0.3	0.01	0.35
T-3P	0.4	0.01	0.25
T-4	0.3	0.01	0.37
T-4P	0.3	0.01	0.26
T-5	0.4	0.03	<0
T-5P	0.4	0.03	0.29
T-6	0.6	0.02	0.44
T-6P	0.9	0.02	0.49
T-7	0.6	0.01	0.55
T-7P	0.6	0.01	0.45
T-8	0.8	0.02	0.53
T-8P	0.7	0.01	0.20
T-9	0.7	0.03	0.40
T-9P	0.8	0.02	0.42
T-10	0.7	0.02	0.37
T-10P	0.8	0.01	0.31
T-11	0.7	0.02	0.41
T-11P	0.8	0.02	0.41
T-12	0.6	0.02	0.50
T-12P	0.8	0.02	0.39
T-13	1.1	0.03	<0
T-13P	1.0	0.03	0.29
T-14	0.2	0.03	0.28
T-14P	0.7	0.01	0.24
T-15	0.5	0.01	0.00
T-15P	0.4	0.00	0.25
T-16	0.4	0.02	0.03
T-16P	0.4	0.03	0.02
T-17	0.4	0.02	0.23
T-17P	0.4	0.01	0.33
T-18	0.4	0.03	0.26
T-18P	0.4	0.01	0.25
T-19	0.7	0.04	<0
T-19P	0.9	0.03	0.34
T-20	0.6	0.01	0.11
T-20P	0.6	0.01	0.29

* "P" following sample number indicates postharvest level.

Preplant Analysis - DTPA Extractable Ni, Cd, and Pb*

Sample	Element (ppm)		
	Ni	Cd	Pb
T-21	0.5	0.02	0.38
T-21P	0.5	0.01	0.32
T-22	0.6	0.02	0.49
T-22P	0.6	0.02	0.45
T-23	0.6	0.03	0.46
T-23P	0.8	0.02	0.58
T-24	0.6	0.03	0.66
T-24P	0.7	0.02	0.48
T-25	0.7	0.01	0.88
T-25P	0.8	0.01	0.76
T-26	0.7	0.01	0.07
T-26P	1.7	0.01	0.40
T-27	0.6	0.04	0.31
T-27P	0.7	0.03	0.35
T-28	0.6	0.03	0.24
T-28P	0.9	0.01	0.32
T-29	0.5	0.01	<0
T-29P	0.7	0.01	0.19
T-30	0.5	0.02	0.25
T-30P	0.5	0.00	0.23
T-31	0.4	0.00	0.29
T-31P	0.4	0.03	0.20
T-32	0.7	0.04	0.41
T-32P	0.7	0.04	0.39
T-33	0.8	0.01	0.27
T-33P	0.9	0.02	0.09
T-34	0.5	0.02	0.24
T-34P	0.5	0.03	0.22
T-35	0.6	0.01	0.44
T-35P	0.7	0.00	0.38
T-36	0.6	0.01	0.27
T-36P	0.8	0.01	0.31
T-37	0.6	0.02	0.13
T-37P	0.6	0.01	0.30

* "P" following sample number indicates postharvest level.

Plant Yield Data

Sample No.	Fresh Weight	Dry Weight
	g./pot	g./pot
T-1	4.18	0.64
T-2	2.94	0.44
T-3	2.54	0.34
T-4	2.44	0.39
T-5	3.24	0.47
T-6	4.42	0.67
T-7	1.71	0.27
T-8	1.82	0.34
T-9	1.65	0.28
T-10	1.09	0.23
T-11	1.42	0.31
T-12	1.66	0.32
T-13	1.37	0.31
T-14	2.19	0.32
T-15	1.71	0.25
T-16	1.86	0.30
T-17	2.58	0.37
T-18	2.59	0.37
T-19	3.43	0.52
T-20	2.04	0.33
T-21	0.89	0.19
T-22	0.75	0.15
T-23	0.77	0.15
T-24	1.20	0.28
T-25	1.60	0.37
T-26	2.00	0.34
T-27	5.09	0.74
T-28	5.15	0.85
T-29	3.50	0.50
T-30	4.80	0.68
T-31	3.65	0.62
T-32	2.98	0.45
T-33	0.95	0.21
T-34	1.25	0.20
T-35	1.43	0.24
T-36	1.40	0.23
T-37	1.46	0.28
Control	6.51	1.34

Although many of the parameters were statistically significant, the "R" values were generally low. Furthermore, "R" values which indicate the proportion that may be attributed to that parameter were low. For example, the best correlation occurred with Boron (R=0.0604). The R^2 value for this relationship was 0.365, i.e., approximately 36.5% of the variation could be attributed to boron. Other parameters which had a fairly high "R" value were % sand, SAR, % clay, pH, % silt, and EC. These parameters are known to affect soil physical problems such as crusting, surface sealing and permeability. Therefore, it is possible that these parameters impacted germination and later plant development.

Plant Tissue Analysis

Table 47, Appendix E, provides the data on the tissue analysis of plants grown in the 37 samples. In evaluating this data, the information by Bauer (1976) for the Consolidated Coal Company, Stranton, North Dakota, was used for comparison. Table 48, Appendix E, provides this comparison. In general, the data obtained was similar to that reported in the literature. The percent magnesium was considerably higher in our analysis. However, it was within the range reported for other species grown on coal mine spoil material. This data was correlated with dry weight of plants to determine which parameters possibly influenced plant growth to the greatest extent. The correlation coefficient for the tissue analysis data versus dry weight of plants is shown in Table 49, Appendix E. Phosphorous, calcium, sodium, boron, manganese and molybdenum had a statistically significant correlation with dry weight. A multiple linear regression using these six parameters gave a R^2 of 0.653, indicating that 65% of the variability is probably attributed to these variables. The coefficient of multiple correlation (R) was 0.808, which is good.

Postharvest Analysis of Soil and Overburden

The postharvest analytical data are shown in Table 50 for the available soil analysis and Table 51 for the total soil analysis. Tables 52 and 53 indicate the correlation coefficient for this data vs. the dry weight of plants.

Postharvest data are meaningless in small pot studies. Several variables such as leaching, root extension, wetting and drying, etc., will affect the results.

Summary of Findings

The following is a summary of findings based on the data collected in this greenhouse study:

1. Germination of barley occurred in all soils.

2. Soil crusting, compaction, cracking and other soil surface problems were very prominent in many of the soils. Future evaluations should consider soil physical parameters.

3. The concentration of metals in the samples prior to planting did not indicate any toxic levels.

4. SAR and EC values were high for several samples and could affect plant growth.

5. Four of the seven sample groups showed significant differences in dry weight yields as related to soil/overburden depth. Yield in the surface layer was generally significantly better.

6. The low shoot/root ratio in some of the samples tested indicated possible toxicity to plant growth. More study is needed in this area.

7. Plant tissue analysis showed that six elements (P, Ca, Na, B, Mn, and Mo) were significantly correlated with plant dry weights.

8. Most of the elements analyzed were within ranges reported in the literature.

The greenhouse serves as a valuable tool for stratifying soil and overburden materials as to their relative productivity. This type of evaluation appears to be a very useful part of a screenable testing program. The combined greenhouse and laboratory data are keys to identifying the nature and extent of further evaluations that are necessary to accurately predict revegetation potential of various soils and overburden.

Table 50 - Postharvest Available Soil Analysis (ppm)

Analysis	Mean	Range	Standard Deviation	Coefficient of Variation
pH	8.3	7.3 - 8.9	0.44	0.05
CEC[1]	---	---	---	---
P	7.7	0 - 51.0	14.26	1.85
K	113.19	46.0 -244.0	51.99	0.46
Zn[2]	---	<0.1 - 4.9	---	---
Cu[2]	---	<0.1 - 1.5	---	---
Mn	23.49	2.6 - 59.0	18.17	0.77
Fe	3.06	0.5 - 11.0	2.66	0.87
DTPA Ni	0.69	0.3 - 1.7	0.25	0.36
DTPA Pb	0.32	0.02 - 0.76	0.13	0.41
DTPA Cd	0.02	0 - 0.04	---	---

1 CEC - see preplant data
2 Majority of samples below detectable limits.

Table 51 - Postharvest Total Soil Analysis (ppm)

Analysis	Mean	Range	Standard Deviation	Coefficient of Variation
B	11.34	5.3 - 19.87	3.62	0.32
Mo*	---	---	---	---
As	26.91	10.2 - 234.3	35.35	1.31

* Majority of samples were below detectable limits.

Table 52 - Postharvest Available vs. Dry Weight Correlation Coefficients

Dry Wt. vs.	Correlation Coefficient
Fe	-.121
Mn	-.474
Cu*	---
Zn*	---
P	.685
K	.355
pH	-.599
DTPA-Ni	.034
DTPA-Pb	-.037
DTPA-Cd	.123

* Majority of samples were below detectable limits.

Table 53 - Postharvest Total vs. Dry Weight Correlation Coefficients

Dry Wt. vs.	Correlation Coefficient
B	-.482
Mo*	---
As	-2.00

* Majority of samples were below detectable limits.

BIBLIOGRAPHY

Bass, N.W., 1932, The Ashland Coal Field, Rosebud, Powder River and Custer Counties, Montana: United States Department of the Interior, Geological Survey Bulletin 831-B.

Bauer, et al, 1976 Physical, Chemical and Biological Aspects of Strip-Mined Lands in Western North Dakota. Final Report to Old West Regional Comm. Nov. 1976, 605 p.

Brown, A., W.C. Culbertson, R.J. Dunham, R.C. Kepferle, and P.R. May, 1954, Strippable Coal in Custer and Powder River Counties, Montana: United States Department of the Interior, Geological Survey Bulletin 995-E.

Gough, L.P., and Shaklette, H.T., 1976, Toxicity of Selected Elements to Plants, Animals, and Man - An Outline, U.S. Geological Survey Open-File Report No. 76-746.

Groenewold, G.H., and Rehm, B.W., 1980, Instability of Contoured Surface-Mined Landscapes in the Northern Great Plains: Causes and Implications, from: Adequate Reclamation of Mined Land? - A symposium, Billings, MT, March 26-27, 1980.

Matson, R.E., and J.W. Blumer, 1973 Quality and Reserves of Strippable Coal, Selected Deposits, Southeastern Montana: Montana Bureau of Mines and Geology, Bulletin 91.

McKay, E.J., 1976, Preliminary Geologic Map and Coal Sections of the Willow Crossing Quadrangle, Rosebud and Powder River Counties, Montana: United States Department of the Interior, Geological Survey Miscellaneous Field Studies Map MF-802.

Montana Department of State Lands, 1980, Rules Pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program, Appendix A

Montana Department of State Lands - Reclamation Division, 1977, Soil and Overburden Guidelines.

Montco Federal Exploration License No. M37254: Data from sixteen drill holes drilled by Intrasearch, Inc. within Cook Mountain Study Area from June to July, 1978.

Renick, B.C., and H.B. Riffenburg, 1929, Geology and Ground Water Resources of Central and Southern Rosebud County, Montana: United States Department of the Interior, Geological Survey Water Supply Paper 600.

Richards, L.A. (Ed.), 1954, Diagnosis and Improvement of Saline and Alkali Soils, United States Department of Agriculture, Agriculture Handbook No. 60.

Underwood, E.J., 1971, Trace Elements in Human and Animal Nutrition, Third Edition, Academic Press, New York.

United States Department of Agriculture, Soil Conservation Service, 1971, Soil Survey of Powder River Area, Montana.

BIBLIOGRAPHY (Cont'd)

United States Department of Agriculture, Soil Survey Staff, 1951, Soil Survey Manual, Agricultural Handbook, No. 18, 503 p.

United States Department of the Interior, Bureau of Land Management, 1977, Guidelines for Reclamation Study Areas - EMRIA Handbook.

United States Department of the Interior, Bureau of Land Management, 1975, Otter Creek Study Site, Montana, EMRIA Report No. 1.

United States Department of the Interior, Bureau of Land Management, 1977, Otter Creek East Study Site, Montana, EMRIA Report No. 47.

United States Department of the Interior, Bureau of Land Management, 1977, Dam Creek Study Site, Montana, EMRIA Report No. 48.

Unites States Department of the Interior, Bureau of Land Management, 1978, Chromo/4 Study Site, Montana, EMRIA Report No. 46.

United States Department of the Interior, Bureau of Land Management, 1978, Shy/6 Study Site, Montana EMRIA Report No. 49.

United States Department of the Interior, Bureau of Land Management, 1978, Newell/28 Study Site, Montana, EMRIA Report No. 50.

United States Department of the Interior, Bureau of Land Management, 1982, Pumpkin Creek Study Area, Montana, EMRIA Report No. 11.

United States Department of the Interior, Geological Survey, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Cook Creek Reservoir Quadrangle, Powder River and Rosebud Counties, Montana: Open File Report 79-84.

United States Department of the Interior, Geological Survey: Data from five United States Geological Survey drill holes drilled within the Cook Mountain Study Area during July of 1979.

United States Department of the Interior, Geologic Survey, Earthquake Information Bulletins.

Warren, W.C., 1959, Reconnaisance Geology of the Birney-Broadus Coal Field, Rosebud and Powder River Counties, Montana: United States Geological Survey Bulletin 1072-J.

APPENDIX A
ENGLISH TO METRIC CONVERSIONS

ENGLISH TO METRIC (SI) CONVERSIONS

Multiply English Units	By	
Inches	25.40	Millimeters (mm)
Feet	0.3048	Meters (m)
Miles	1.609	Kilometers (km)
Acres	0.4047	Hectares (ha)
	0.004047	Square Kilometers (km^2)
Square Miles	2.590	Square Kilometers (km^2)
Acre-Feet	0.001233	Cubic Hectometers (hm^3)
Cubic Yard	0.7646	Cubic Meter (m^3)
Feet Per Mile	0.1894	Meters Per Kilometer (m/km)
Btu Per Pound	0.556	Kilogram Calories Per Kilogram (kcal/kg)
Pounds	453.60	Grams (g)

APPENDIX B
GEOLOGY

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: C. Murphy Log X

Driller: M. Hunnicutt Log

Project: Montco Fed. Expl Hole No.: 24424-1

State Montana County Rosebud

Location: Sec: 24 T. 2S R. 44E

Elevation: 3343.7

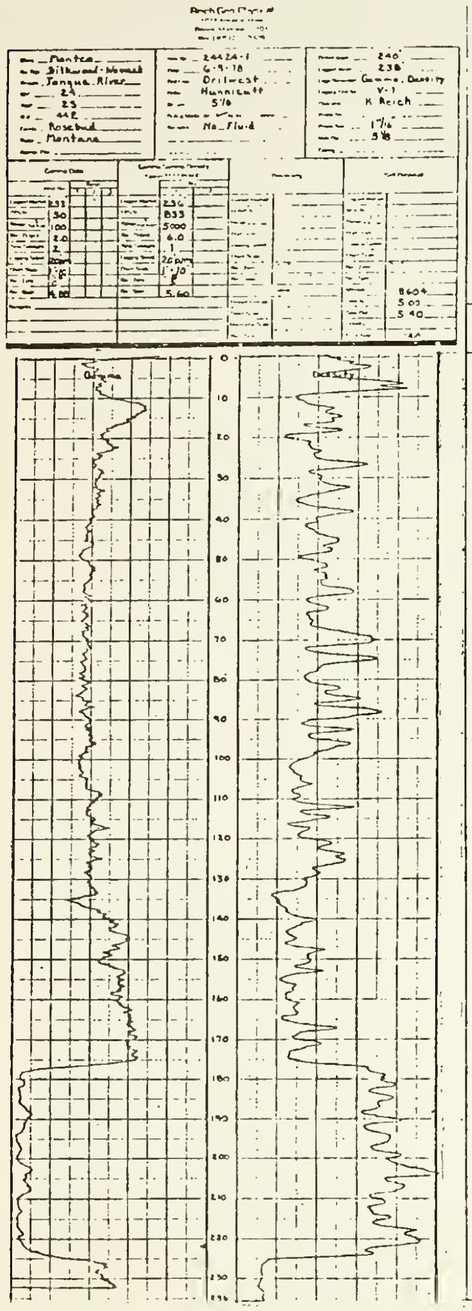
Coordinates: N 619,732 E 2,834,922

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	15.0			CLINKER
15.0	18.0			carb. SH
18.0	47.0			soft yellow SS
47.0	49.0			hd. SS
49.0	134.0			soft brownish-yellow SS
134.0	138.0			hd. SS
138.0	177.0			gr. sandy SH
177.0	225.0			COAL (K)

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: C. Murphy Log X

Driller: M. Hunnicutt Log

Project: Montco Fed. Expl. Hole No.: 24424-1

State Montana County Rosebud

Location: Sec: 24 T. 2S R. 44E

Elevation: 3343.7

Coordinates: N 619,732 E 2,834,922

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
225.0	240.0			gr. sandy SH
240.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 24424-2

Client: Montco

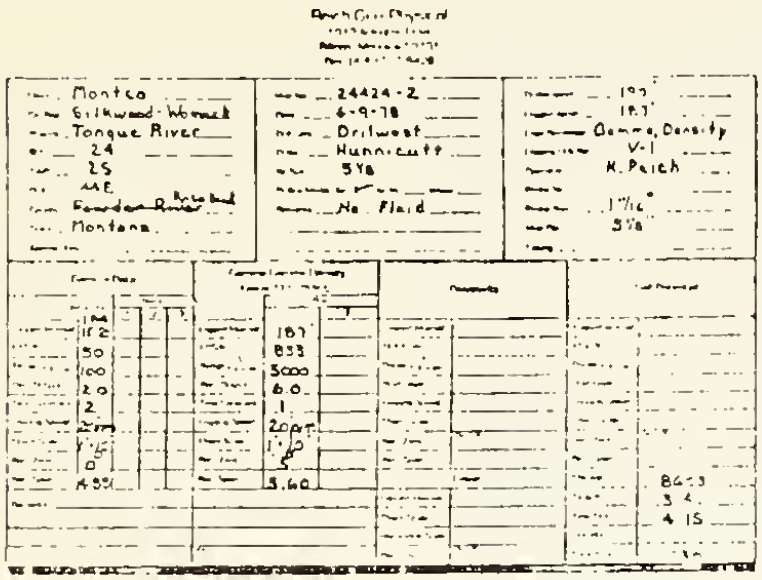
State Montana County Rosebud

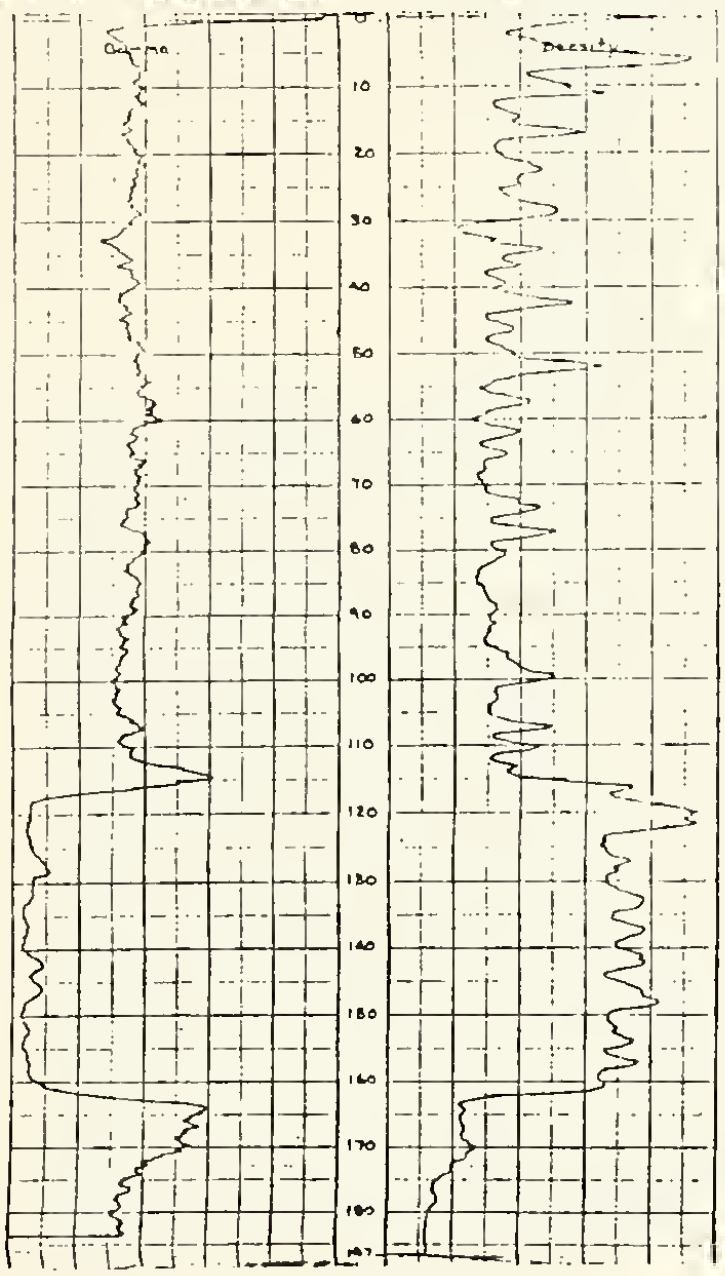
Geologist: C. Murphy Log X

Location: T. 2S R. 44E

Driller: M. Hunnicutt Log

Sec: 24 Elevation: 3275.8





Coordinates: N 619,179 E 2,833,365

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
0.0	10.0			bn. SAND
10.0	29.0			soft SS
29.0	34.0			hd. SS
34.0	114.5			soft SS
114.5	116.0			SH
116.0	163.0			COAL (K)
163.0	175.0			gr. shaley SS
175.0	190.0			gr. soft SS
190.0				TD

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: R. Womack Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 24518-2(pilot)

State Montana County Powder River

Location: Sec: 18 T. 2S R. 45E

Elevation: 3292.4

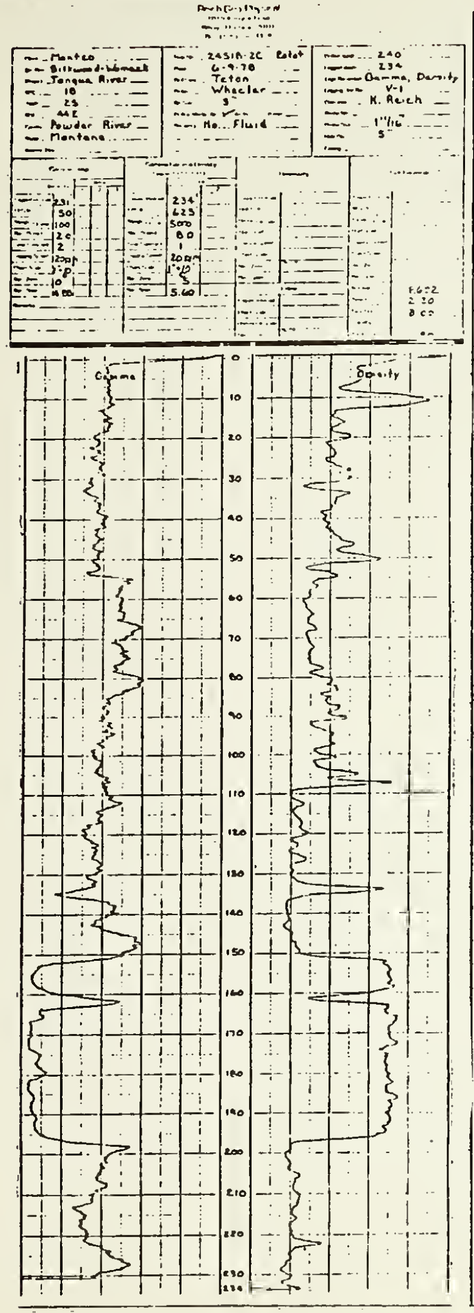
Coordinates: N 622,781 E 2,835,518

Drilling Contractor: Teton

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	12.0			bn. sandy CLAY
12.0	44.0			yellowish to grayish bn. SAND (weathered ss)
44.0	54.0			yellowish bn. soft v.f.g. SS
54.0	75.0			pale gr. soft sandy SH
75.0	85.0			pale gr. soft sandy SH w/ coal stringers
85.0	123.0			yellowish bn. soft v.f.g shaley SS
123.0	134.0			dk. gr. shaley SS
134.0	135.6			COAL
135.6	142.5			gr. CLAYST & carb. sh
142.5	152.0			gr. sandy SH
152.0	161.5			COAL (UK)
161.5	162.9			gr. CLAYST
162.9	198.0			COAL (MK)
198.0	201.0			gr. CLAYST

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: R. Womack Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 24518-2(pilot)

State Montana County Powder River

Location: Sec: 18 T. 2S R. 45E

Elevation: 3292.4

Coordinates: N 622,781 E 2,835,518

Drilling Contractor: Teton

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
201.0	222.0			gr. sandy SH
222.0	240.0			gr. sandy SH w/ coal stringers
240.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 24518-2C

Client: Montco

State Montana County Powder River

Geologist: R. Womack Log X

Location:

Driller: K. Wheeler Log

Sec 18 T. 2S R. 45E

Elevation: 3291.0

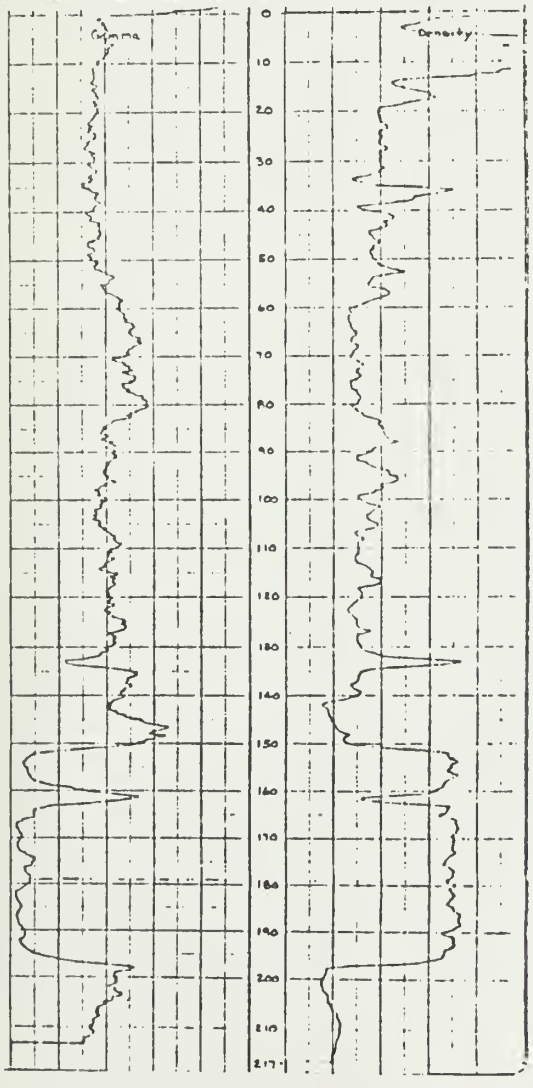
Coordinates: N 622,789 E 2,835,510

Drilling Contractor: Teton

Drilling Method: Rotary Diameter: NX

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	12.0			bn. sandy CLAY
12.0	44.0			yellowish to grayish bn. SAND (weathered ss)
44.0	53.5			yellowish bn. soft v.f.g. SS
53.5	75.0			pale gr. soft sandy SH
75.0	85.0			pale gr. soft sandy SH w/ coal stringers
85.0	123.0			yellowish bn. soft v.f.g. shaley SS
123.0	133.0	128.5		dk. gr. shaley SS
133.0	134.6			COAL
134.6	141.5			gr. CLAYST & carb.sh
141.5	152.0			gr. sandy SH (some carb material)
152.0	161.5			COAL (UK)
161.5	162.9			gr. CLAYST
162.9	197.8			COAL (MK)
197.8	201.0	199.3		gr. CLAYST
201.0	220.0			gr. sandy SH
220.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 24530-2(pilot)

Client: Montco

State Montana County Powder River

Geologist: J. Hamilton Log X

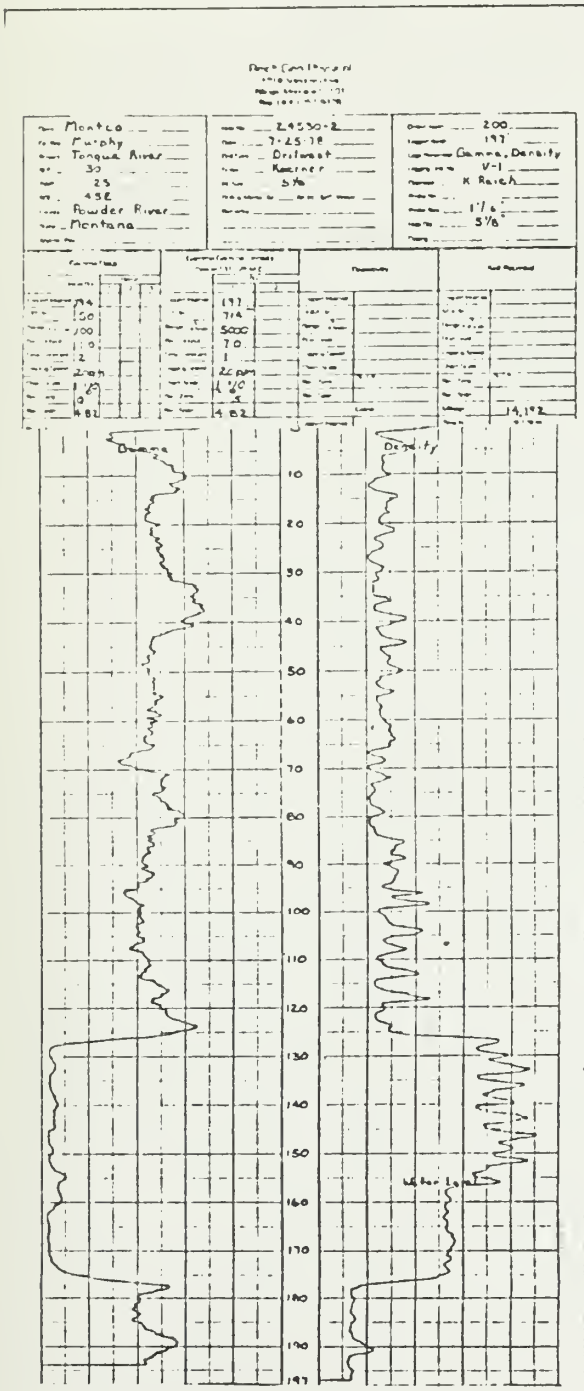
Location:

T. 2S R. 45E

Driller: V. Koerner Log

Sec: 30

Elevation: 3232.4



Coordinates: N 613,477 E 2,836,317

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 7/25/78 Completed: 7/25/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
0.0	14.0			yellowish bn. CLAYST
14.0	33.0			gr. & bn. shaley SILTST & SS
33.0	43.0			pale gr. SH, coal stringers
43.0	88.0			greyish bn. v.f.g. shaley SS
88.0	96.0			gr. sandy & silty SH
96.0	116.0			gr. shaley f.g. SS
116.0	123.5			gr. SH
123.5	126.8			carb. SH, coal lenses
126.8	178.0			COAL (K)
178.0	179.5			gr. CLAYST
179.5	190.5			gr. f.g. SS
190.5	193.0			gr. CLAYST
193.0	200.0			gr. sandy SH
200.0				TD

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: C. Murphy Log X

Driller: V. Koerner Log

Project: Montco Fed. Expl Hole No.: 24530-2C

State Montana County Powder River

Location: Sec: 30 T. 2S R. 45E

Elevation: 3232.4

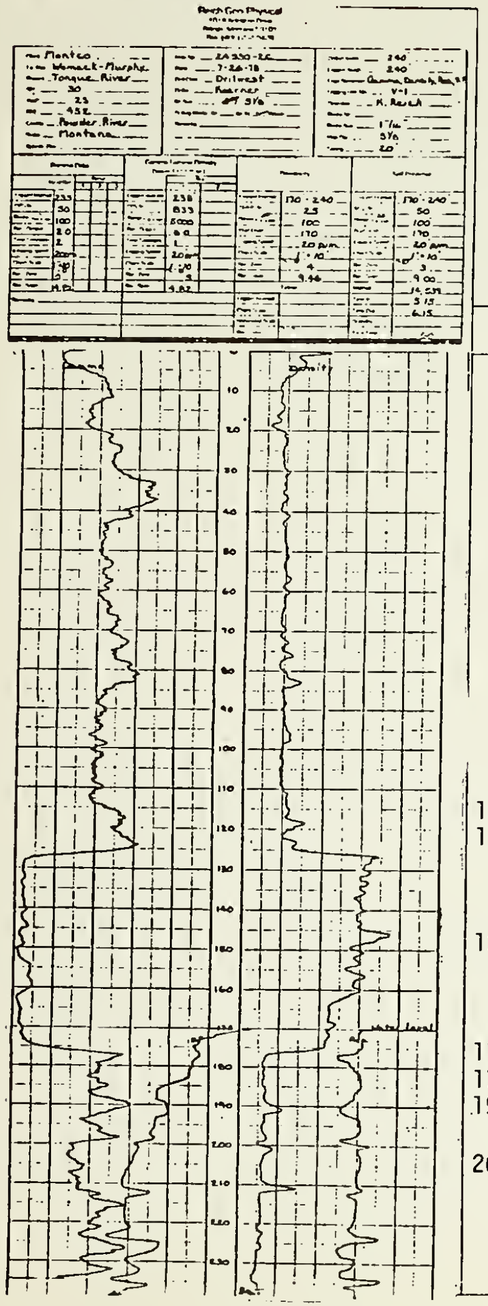
Coordinates: N 613,477 E 2,836,310

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: NX

Date Started: 7/26/78 Completed: 7/26/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	14.0			yellowish bn. CLAYST
14.0	33.0	15.0		gr. & bn. shaley SILTST & SS
33.0	43.0			pale gr. SH, coal stringers
43.0	88.5			greyish bn. v.f.g. shaley SS
88.5	96.0			gr. sandy & silty SH
96.0	114.0			gr. shaley v.f.g. SS
114.0	123.5			gr. SH
123.5	126.8			carb. SH, coal lenses
126.8	177.0			COAL (K)
177.0	179.0	177.5		gr. CLAYST
179.0	190.0			gr. v.f.g. SS
190.0	200.0			gr. interbedded CLAYST & v.f.g. SS
200.0	212.5			gr. f.g. SS, hd. at top

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: C. Murphy Log X

Driller: V. Koerner Log

Project: Montco Fed. Expl. Hole No.: 24530-2C

State Montana County Powder River

Location: Sec: 30 T. 2S R. 45E

Elevation: 3232.4

Coordinates: N 613,477 E 2,836,310

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: NX

Date Started: 7/26/78 Completed: 7/26/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
212.5	223.0			gr. sandy SH
223.0	226.0			gr. hd. SS
226.0	234.0			gr. SH
234.0	236.0			gr. hd. SS
236.0	240.0			gr. SH
240.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl Hole No.: 24530-3W

Client: Montco State Montana County Powder River

Geologist: J. Hamilton Log X

Driller: V. Koerner Log

Location: Sec: 30 T. 2S R. 45E

Elevation: 3260.6

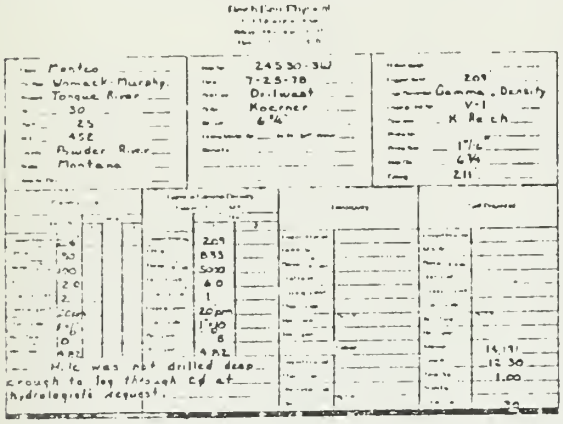
Coordinates: N 611,018 E 2,836,482

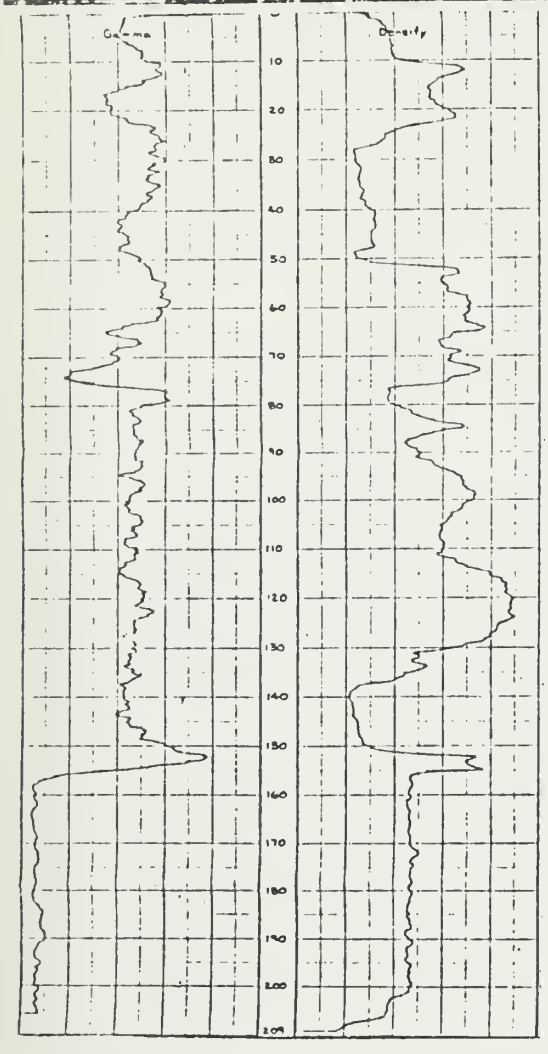
Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 7/25/78 Completed: 7/25/78

Depth: Top Soil: Alluvium: Water:





Depth		Cored Interval	Lithology	Comments
0.0	8.0			bn. silty CLAY
8.0	17.0			greyish bn. SILTST
17.0	23.5			yellowish bn. SS & SILTST
23.5	41.0			gr. to bn. CLAYSTONE
41.0	54.5			bn./gr. SS & SILTST
54.5	64.5			carb. SH
64.5	72.5			gr. SILTST
72.5	76.5			COAL (poor quality)
76.5	81.0			carb. SH
81.0	114.0			gr. SILTST
114.0	115.5			gr. hd. f.g. SS
115.5	156.0			gr. SILTST & CLAYST
156.0	209.0			COAL (K)
209.0	220.0			gr. SILTST
220.0				TD

Cased to 215' for piezometer

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: R. Womack Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 24532-1

State Montana County Powder River

Location: Sec: 32 T. 2S R. 45E

Elevation: 3348.2

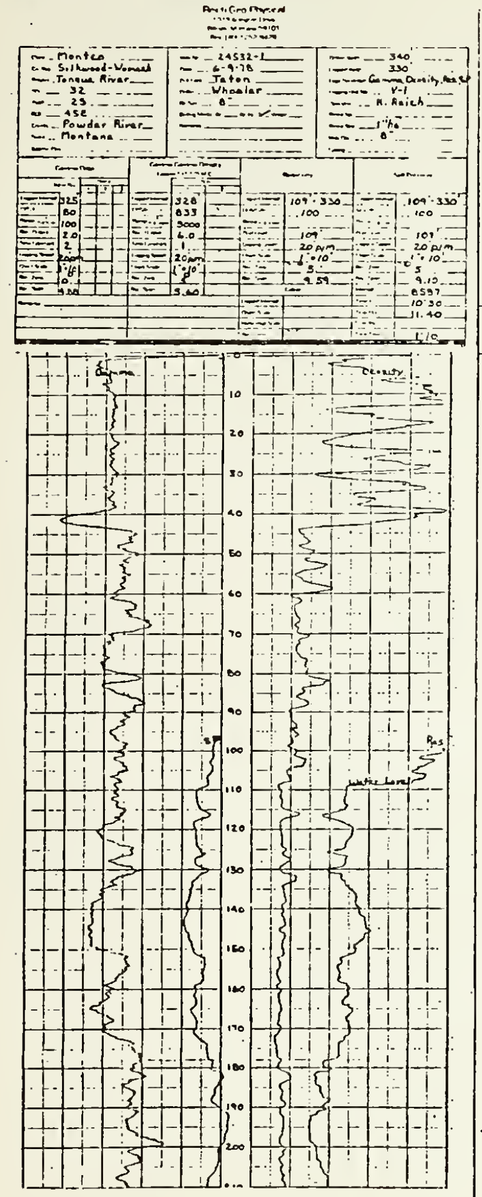
Coordinates: N 609,706 E 2,842,624

Drilling Contractor: Teton

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: 5' Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	5.0			bn. CLAY
5.0	39.5			CLINKER
39.5	43.8			COAL (S)
43.8	60.5			yellowish bn. SH
60.5	71.0			pale gr. sandy SH
71.0	82.5			pale gr. shaley SS
82.5	130.0			pale gr. sandy SH
130.0	138.5			carb. SH
138.5	152.0			pale gr. shaley SS
152.0	159.0			pale gr. sandy SH
159.0	173.5			pale gr. shaley SS
173.5	201.0			pale gr. sandy SH, coal stringers
201.0	210.0			carb. SH

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: R. Womack Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 24532-1

State Montana County Powder River

Location: Sec: 32 T. 2S R. 45E

Elevation: 3348.2

Coordinates: N 609,706 E 2,842,624

Drilling Contractor: Teton

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: 5' Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
210.0	236.5			gr. sandy SH
236.5	239.2			COAL (UK)
239.2	242.5			carb. SH
242.5	294.0			COAL (MK)
294.0	340.0			gr. sandy SH
340.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 24532-2

Client: Montco

State Montana County Powder River

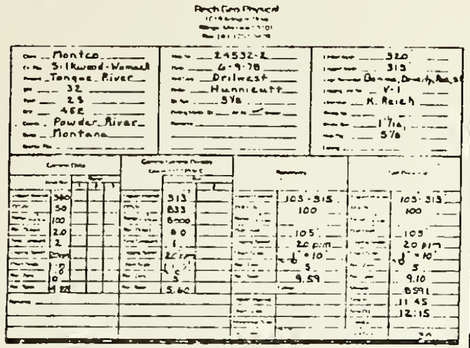
Geologist: H. Silkwood Log X

Location:

Driller: M. Hunnicutt Log

Sec: 32 T. 2S R. 45E

Elevation: 3287.9



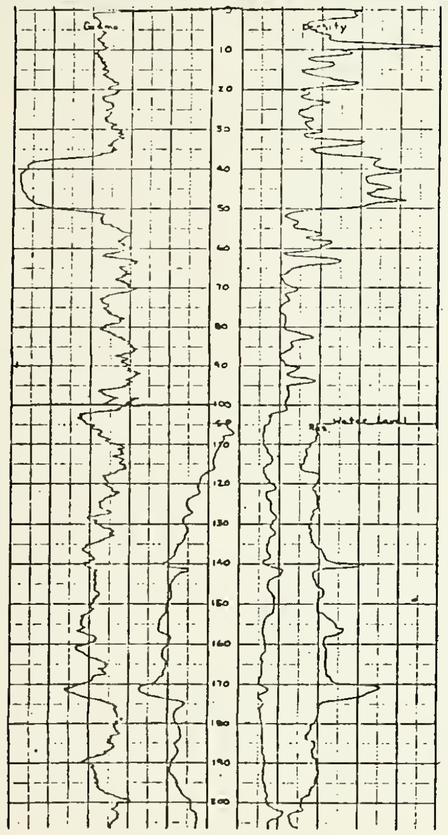
Coordinates: N 605,637 E 2,842,714

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	6.5			bn. CLAY
6.5	10.0			clinker GRAVELS
10.0	20.0			bn. CLAY
20.0	37.5			pale gr. SH
37.5	51.5			COAL (S)
51.5	67.5			gr. sandy SH, hd. ss lenses
67.5	72.0			gr. sandy SH,carb & coal stringers
72.0	171.0			gr. shaley SS
171.0	175.0			gr. hd. SS
175.0	207.0			gr. hd. sandy SH

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 24532-2

Client: Montco

State Montana County Powder River

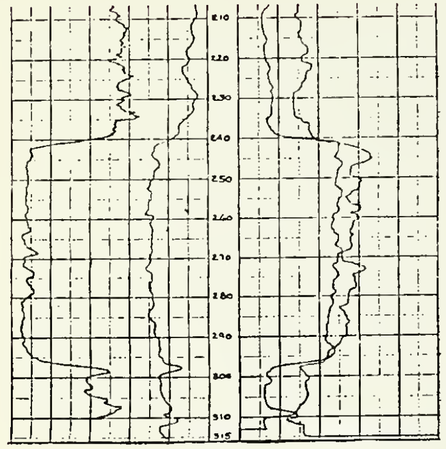
Geologist: H. Silkwood Log X

Location:

Driller: M. Hunnicutt Log

Sec: 32 T. 2S R. 45E

Elevation: 3287.9



Coordinates: N 605,637 E 2,842,714

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:

Depth		Cored Interval	Lithology	Comments
207.0	222.0			carb. SH
222.0	241.0			gr. sandy SH
241.0	297.5			COAL (K)
297.5	300.5			gr. CLAYST
300.5	307.5			gr. soft SS
307.5	316.0			gr. sandy SH
316.0	320.0			gr. hd. SS
320.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 34412-1

Client: Montco

State Montana County Rosebud

Geologist: H. Silkwood Log

Driller: K. Wheeler Log X

Location: Sec: 12 T. 3S R. 44E

Elevation: 3201.6

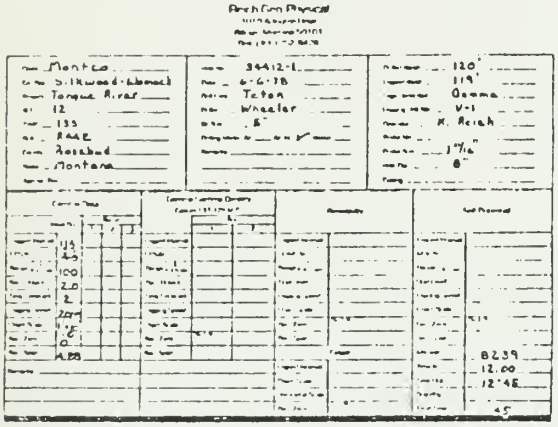
Coordinates: N 598,705 E 2,834,706

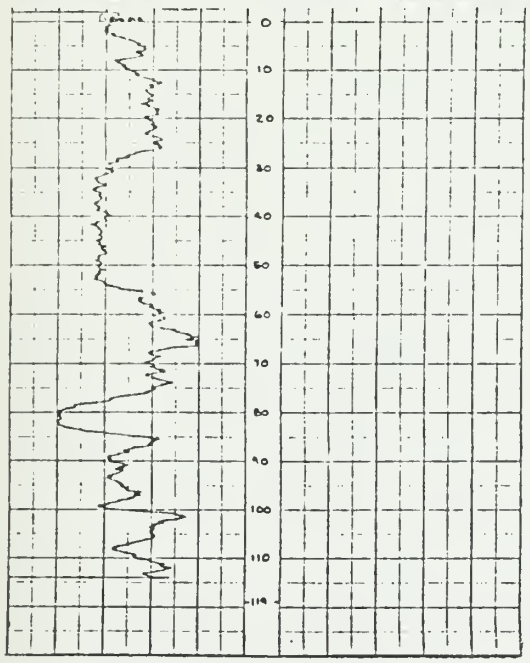
Drilling Contractor: Teton

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/6/78 Completed: 6/6/78

Depth: Top Soil: Alluvium: Water:





Depth		Cored Interval	Lithology	Comments
0.0	120.0			CLINKER
120.0				TD

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 3454-1

State Montana County Rosebud

Location: Sec: 4 T. 3S R. 45E

Elevation: 3331.6

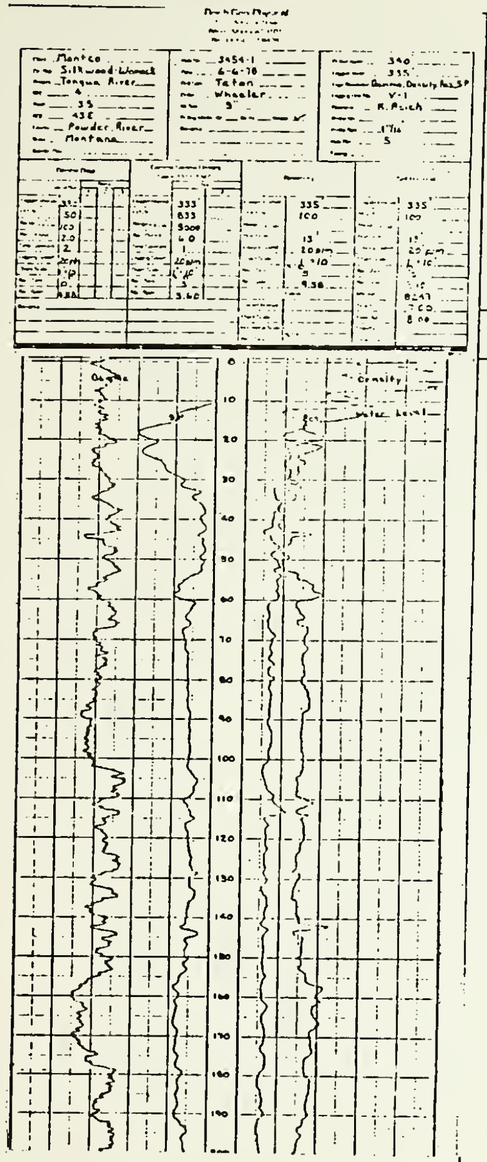
Coordinates: N 603,450 E 2,848,337

Drilling Contractor: Teton

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/6/78 Completed: 6/6/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	40.0			CLINKER
40.0	222.0			gr. sandy SH

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log X

Driller: K. Wheeler Log

Project: Montco Fed. Expl. Hole No.: 3454-1

State Montana County Rosebud

Location: Sec: 4 T. 3S R. 45E

Elevation: 3331.6

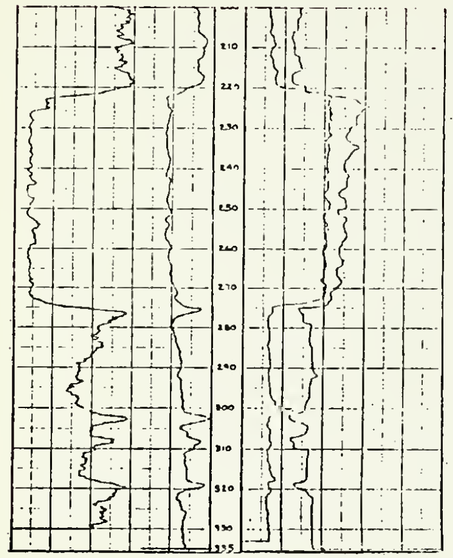
Coordinates: N 603,450 E 2,848,337

Drilling Contractor: Teton

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/6/78 Completed: 6/6/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
222.0	274.5			COAL (K)
274.5	279.0			gr. sandy SH
279.0	302.0			gr. SS
302.0	304.5			gr. SH
304.5	319.5			gr. shaley SS
319.5	340.0			gr. sandy SH
340.0				TD

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log X

Driller: M. Hunnicutt Log

Project: Montco Fed. Expl. Hole No.: 3456-1(offset)

State Montana County Powder River

Location: Sec: 6 T. 3S R. 45E

Elevation: 3251.2

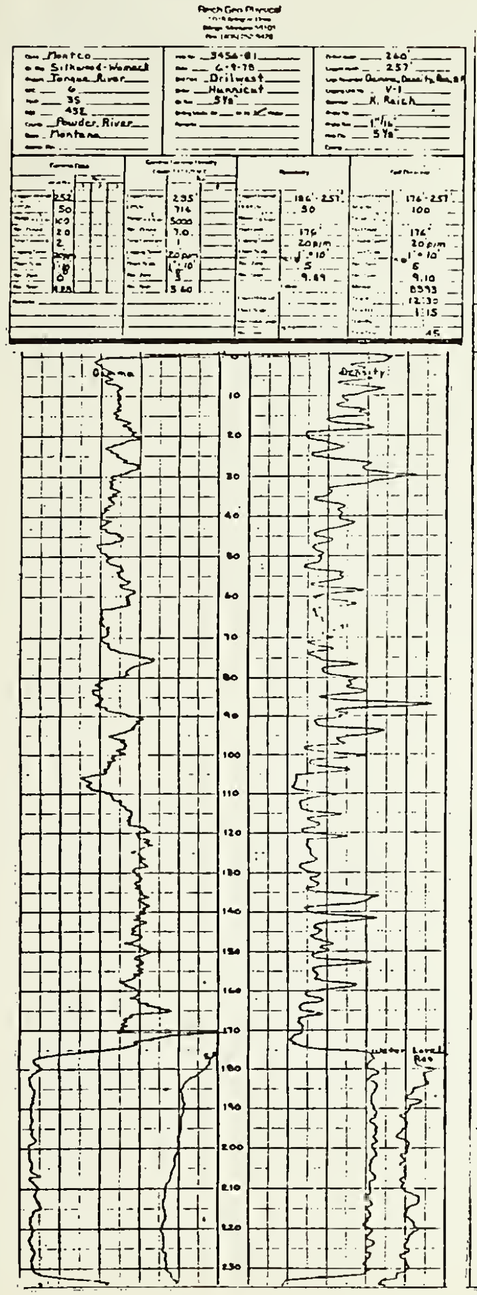
Coordinates: N 604,155 E 2,840,054

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	8.0			CLINKER
8.0	17.0			SAND & broken rock
17.0	30.0			gr. SH
30.0	52.5			yellow soft SS
52.5	59.0			carb. SH
59.0	63.0			gr. SH
63.0	73.0			yellow soft SS
73.0	80.0			med. gr. sandy SH, coal stringers
80.0	91.0			yellow SS
91.0	106.0			yellow sandy SH
106.0	110.0			gr. hd. SS
110.0	125.0			gr. sandy SH
125.0	130.0			carb. SH
130.0	140.0			gr. SH, carb stringers
140.0	175.8			dk. gr. SH
175.8	233.0			COAL (K)

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log X

Driller: M. Hunnicutt Log

Project: Montco Fed. Expl. Hole No.: 3456-1(offset)

State Montana County Powder River

Location: Sec: 6 T. 3S R. 45E

Elevation: 3251.2

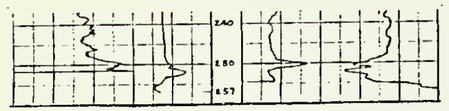
Coordinates: N 604,155 E 2,840,054

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/9/78 Completed: 6/9/78

Depth: Top Soil: Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
233.0	253.0			med. gr. sandy SH
253.0	257.0			gr. hd. SS
257.0	260.0			gr. sandy SH
260.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 3458-1W

Client: Montco

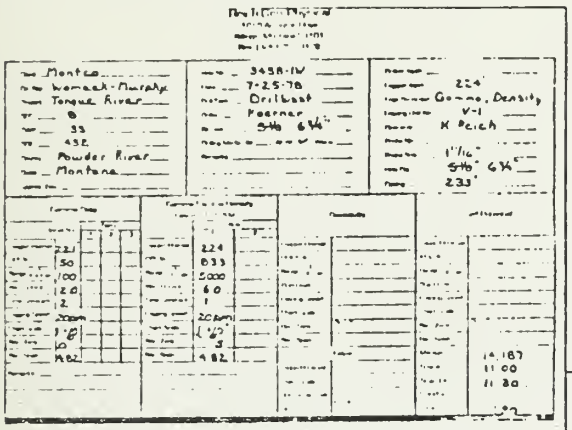
State Montana County Powder River

Geologist: J. Hamilton Log X

Location: X T. 3S R. 45E

Driller: V. Koerner Log

Sec: 8 Elevation: 3241.3



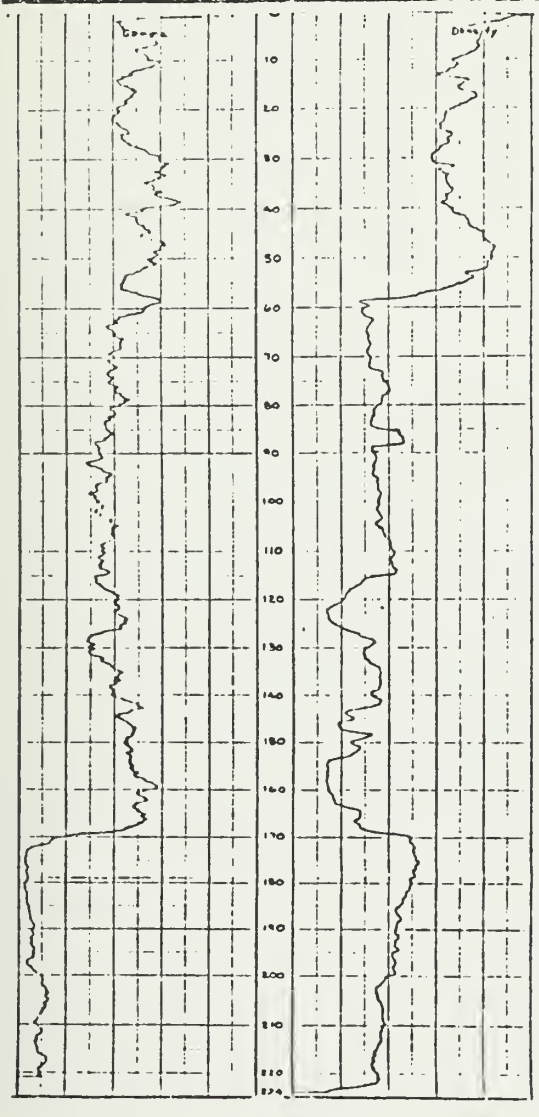
Coordinates: N 598,043.8 E 2,845,944.4

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 7/23/78 Completed: 7/23/78

Depth: Top Soil: 5' Alluvium: Water:



Depth		Cored Interval	Lithology	Comments
0.0	5.0			bn. CLAY
5.0	28.0			bn. SILTST
28.0	63.5			gr. sandy SH, carb. stringers
63.5	135.5			gr. v.f.g. SS, shaley layers
135.5	165.0			gr. sandy SH, carb. stringers
165.0	169.5			carb. SH
169.5	223.5			COAL (K)
223.5	235.0			gr. CLAYST
235.0				TD (Cased to 233.7'

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 3458-2W

Client: Montco State Montana County Powder River

Geologist: J. Hamilton Log X

Driller: V. Koerner Log

Location: X T. 3S R. 45E

Sec: 8 Elevation: 3265.2

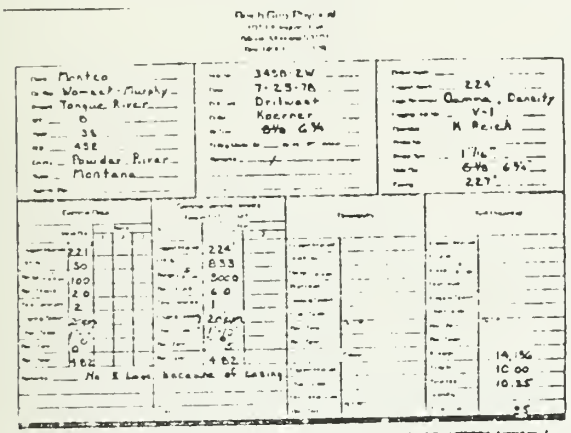
Coordinates: N 597,913 E 2,842,116

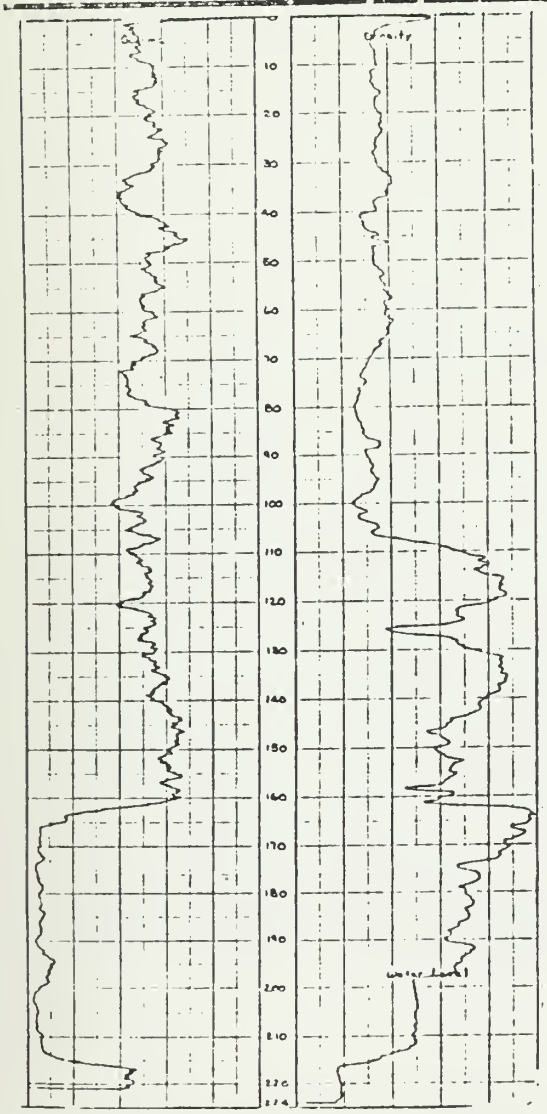
Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 7/23/78 Completed: 7/23/78

Depth: Top Soil: 5' Alluvium: Water:





Depth		Cored Interval	Lithology	Comments
0.0	5.0			dk. grayish-bn. silty CLAY
5.0	9.0			yellow SILT
9.0	15.5			grayish bn. SILTST
15.5	33.0			gr. CLAYSTONE & SILTST
33.0	41.0			bn. v.f.g. SS
41.0	72.0			gr. sandy SH, coal stringers
72.0	81.0			grayish bn. v.f.g. SS
81.0	148.0			gr. silty CLAYSTONE, hd. ss at 100'
148.0	163.0			carb. SH
163.0	216.5			COAL (K)
216.5	228.0			gr. CLAYSTONE
228.0			TD	(cased 227.4' for piezometer)

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log

Driller: M. Hunnicutt Log X

Project: Montco Fed. Expl. Hole No.: 3458-3(pilot)

State Montana County Powder River

Location: Sec: 8 T. 3S R. 45E Elevation: 3243.6

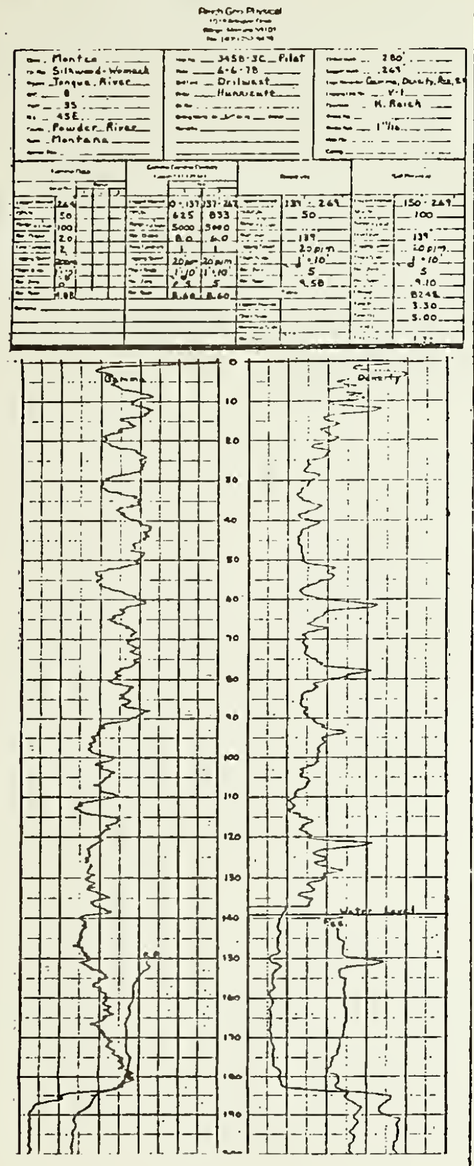
Coordinates: N 595,043 E 2,844,382

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/6/78 Completed: 6/6/78

Depth: Top Soil: 5' Alluvium: Water: 120' - 140'



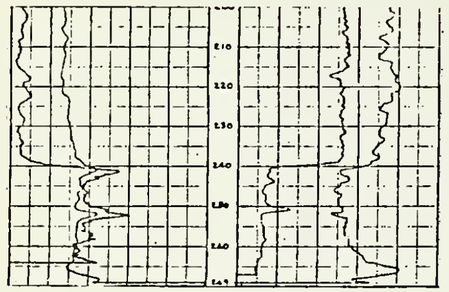
Depth		Cored Interval	Lithology	Comments
0.0	10.4			reddish bn. CLAY
10.4	15.0			gr. CLAY, carb. stringers
15.0	20.3			bn. f.g. SS
20.3	33.8			bn. interbedded CLAYST & SS
33.8	42.0			tan hd. SH
42.0	52.0			gr. CLAYST
52.0	56.0			tan f.g. SS, CLAYST
56.0	68.5			gr. shaley SS, coal stringers
68.5	78.0			gr. SH, carb. & coal stringers
78.0	94.0			gr. SS & SH, coal stringers
94.0	100.0			gr. f.g. SS
100.0	109.5			gr. v.f.g. shaley SS, coal stringers
109.5	114.5			hd. calc. SH
114.5	121.0			gr. v.f.g. SS & SH
121.0	130.0			pale gr. v.f.g. SS
130.0	154.0			gr. shaley SS
154.0	178.5			gr. soft SS & SH
178.5	184.5			carb. SH
184.5	240.8			COAL (K)

IntraSearch
Billings, Montana 59102

Client: Montco

Geologist: H. Silkwood Log

Driller: M. Hunnicutt Log X



Project: Montco Fed. Expl. Hole No.: 3458-3(pilot)

State Montana County Powder River

Location: Sec: 8 T. 3S R. 45E Elevation: 3243.6

Coordinates: N 595,043 E 2,844,382

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter:

Date Started: 6/6/78 Completed: 6/6/78

Depth: Top Soil: 5' Alluvium: Water: 120' - 140'

Depth		Cored Interval	Lithology	Comments
240.8	262.0			gr. soft SH
262.0	268.0			gr. hd. v.f.g. SS
268.0	280.0			gr. soft sandy SH
280.0				TD

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl. Hole No.: 3458-3C

Client: Montco

State Montana County Powder River

Geologist: H. Silkwood Log X

Location: T. 3S R. 45E

Driller: M. Hunnicutt Log

Sec: 8 Elevation: 3244.0

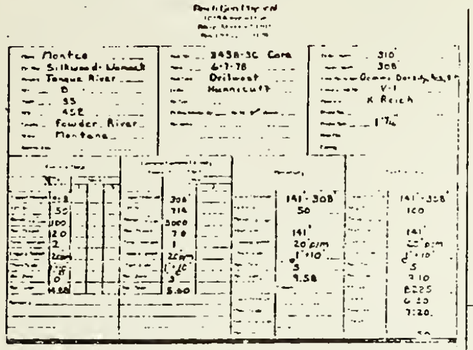
Coordinates: N 595,049 E 2,844,388

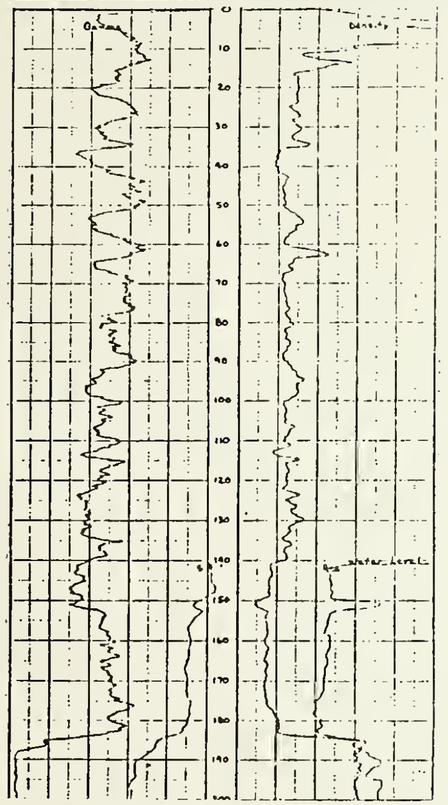
Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Date Started: 6/6/78 Completed: 6/7/78

Depth: Top Soil: 5' Alluvium: Water: 120'-140'





Depth		Cored Interval	Lithology	Comments
0.0	10.4	10.0		reddish bn. CLAY
10.4	15.0			gr. CLAY,carb. stringers
15.0	20.3			bn. f.g. SS
20.3	33.8			interbedded bn. CLAYST & SS
33.8	40.8			gr. hd. SH
40.8	50.6			gr. CLAYST
50.6	55.9			tan f.g. SS
55.9	67.6			gr. shaley SS, coal stringers
67.6	76.9			gr. SH, carb. & coal stringers
76.9	92.9			gr. SS & SH, coal stringers
92.9	99.2			gr. f.g. SS
99.2	109.2			gr. v.f.g. shaley SS, coal stringers
109.2	114.5			hd. calc. SH
114.5	122.5			gr. v.f.g. SS & SH
122.5	130.0			pale gr. v.f.g. SS
130.0	153.0			gr. shaley SS
153.0	178.5			gr. soft SS & SH
178.5	185.0			carb. SH
185.0	241.0			COAL (K)

IntraSearch
Billings, Montana 59102

Project: Montco Fed. Expl Hole No.: 3458-3C

Client: Montco

Siete Montana County Powder River

Geologist: H. Silkwood Log X

Location: T. 3S R. 45E

Driller: M. Hunnicutt Log

Sec: 8 Elevation: 3244.0

Coordinates: N 595,049 E 2,844,388

Drilling Contractor: Drilwest

Drilling Method: Rotary Diameter: 6 7/8"

Dete Started: 6/6/78 Completed: 6/7/78

Depth: Top Soil: 5' Alluvium: Water: 120'- 140'

Depth		Cored Interval	Lithology	Comments
241.0	261.0	242.2		gr. soft SH
261.0	266.0			gr. hd. v.f.g. calc. SS
266.0	291.5			gr. interbedded soft sandy SH & mod hd. calc. ss
291.5	305.0			gr. soft sandy SH
305.0	310.0			gr. mod. hd. f.g. calc SS
310.0				TD

APPENDIX C
COAL RESOURCES

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 24, T. 2 S., R. 44 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED [1/]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2/] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0.18	0.17	0.94	2.1	85,714
50-100	1.65	2.84	1.72	19.1	86,387
100-150	5.66	14.13	2.50	65.9	85,888
150-200	3.65	11.99	3.29	42.5	85,882
Over 200	0.10	0.35	3.50	1.1	90,909
TOTAL	11.24	TOTAL 29.48	AVERAGE [3/] 2.63	TOTAL 130.7	

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 48.5 feet.

2/ Knobloch Coal has been burned or eroded away in 80 percent (509.3 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 4

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 18, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES 2/ MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	4.37	3.45	0.79	53.4	81,835
50-100	12.30	18.15	1.48	150.1	81,945
100-150	16.60	39.81	2.40	202.5	81,975
150-200	15.53	51.89	3.34	189.4	81,996
Over 200	4.54	20.54	4.52	55.5	81,802
TOTAL	53.34	TOTAL 133.84	AVERAGE 3/ 2.51	TOTAL	650.9

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 46.3 feet.

2/ Knobloch Coal has been burned or eroded away in 0 percent (0 acres) of this section.

3/ Average shown is a weighted. average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 5

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
S½ SECTION 29, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED [1]

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES [2] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0	0	---	0	---
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	30.21	159.85	5.29	320.0	94,406
TOTAL	30.21	TOTAL 159.85	AVERAGE [3] 5.29	TOTAL	320.0

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 53.3 feet.

2/ Knobloch Coal has been burned or eroded away in 0 percent (0 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 6

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 30, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED [1/]

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES [2/] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	2.73	2.22	0.81	29.3	93,174
50-100	13.15	17.65	1.34	141.5	92,933
100-150	18.79	40.72	2.17	202.2	92,928
150-200	11.84	35.92	3.03	127.4	92,936
Over 200	14.37	54.83	3.82	154.6	92,250
TOTAL	60.88	TOTAL 151.34	AVERAGE [3/] 2.49	TOTAL 655.0	

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 52.5 feet.

2/ Knobloch Coal has been burned or eroded away in 0 percent (0 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 7

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 32, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED [1]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0.30	0.48	1.60	3.0	100,000
100-150	2.68	5.44	2.03	27.0	99,259
150-200	19.02	54.87	2.89	191.8	99,166
Over 200	41.40	163.20	3.94	417.7	99,114
TOTAL	63.40	TOTAL 223.99	AVERAGE [3] 3.53	TOTAL	639.5

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 56.0 feet.

2/ Knobloch Coal has been burned or eroded away in 0 percent (0 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 8

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
W½ SECTION 4, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES 2/ MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0	0	---	0	---
100-150	0.71	1.71	2.41	7.2	98,611
150-200	12.92	35.85	2.78	130.9	98,701
Over 200	18.07	73.71	4.08	182.9	98,797
	TOTAL 31.70	TOTAL 111.27	AVERAGE 3/ 3.51	TOTAL 321.0	

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 55.8 feet.

2/ Knobloch Coal has been burned or eroded away in 0 percent (0 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 9

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 6, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0.32	0.24	0.76	3.2	100,000
50-100	2.19	2.68	1.23	21.9	100,000
100-150	10.19	21.36	2.10	101.9	100,000
150-200	16.33	46.04	2.82	163.3	100,000
Over 200	2.60	8.60	3.31	26.0	100,000
TOTAL	31.63	TOTAL 78.92	AVERAGE 3/ 2.50	TOTAL	316.3

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 56.5 feet.

2/ Knobloch Coal has been burned or eroded away in 54 percent (367.1 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 10

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 8, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
KNOBLOCH COALBED [1/]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2/] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0.57	0.92	1.61	5.9	96,610
100-150	14.35	31.87	2.22	148.8	96,438
150-200	33.89	99.07	2.92	351.3	96,470
Over 200	11.52	40.40	3.51	119.3	96,563
TOTAL	60.33	TOTAL 172.26	AVERAGE [3/] 2.85	TOTAL 625.3	

FOOTNOTES:

1/ Thickness of Knobloch Coalbed in this section averages 54.5 feet.

2/ Knobloch Coal has been burned or eroded away in 2 percent (14.7 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 25.

Overburden volumes and ratios includes interburden and coalbeds younger than the Knobloch.

Table 11

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 24, T. 2 S., R. 44 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED [1]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0	0	---	0	---
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
TOTAL	0	TOTAL 0	AVERAGE [3] ---	TOTAL	0

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 0 feet.

2/ Sawyer Coal has been burned or eroded away in 100 percent (640 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 12

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 18, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0.11	0.31	2.82	4.0	27,500
50-100	0.13	0.43	3.31	5.0	26,000
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
	TOTAL 0.24	TOTAL 0.74	AVERAGE 3/ 3.09	TOTAL 9.0	

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 15.0 feet.

2/ Sawyer Coal has been burned or eroded away in 99 percent (641.9 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 13

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
S½ SECTION 29, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES 2/ MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	4.99	10.69	2.14	201.0	24,826
50-100	1.32	5.67	4.30	53.3	24,766
100-150	0.10	0.68	6.80	4.1	24,390
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
	TOTAL 6.41	TOTAL 17.04	AVERAGE 3/ 2.66	TOTAL 258.4	

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 14.0 feet.

2/ Sawyer Coal has been burned or eroded away in 19 percent (61.6 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 14

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 30, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED, INDICATED, AND INFERRED RESERVES 2/ MILLION TONS.	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	3.18	7.24	2.28	128.4	24,766
50-100	0	0	---	0	---
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
TOTAL	3.18	TOTAL 7.24	AVERAGE 3/ 2.28	TOTAL	128.4

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 14.0 feet.

2/ Sawyer Coal has been burned or eroded away in 80 percent (526.6 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 15

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 32, T. 2 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED [1]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	8.10	9.82	1.21	304.8	26,575
50-100	0.69	3.14	4.55	26.0	26,539
100-150	0.24	1.60	6.67	9.0	26,667
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
TOTAL	9.03	TOTAL 14.56	AVERAGE [3] 1.61	TOTAL 339.8	

FOOTNOTES:

[1] Thickness of Sawyer Coalbed in this section averages 15.0 feet.

[2] Sawyer Coal has been burned or eroded away in 47 percent (299.7 acres) of this section.

[3] Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 16

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
W½ SECTION 4, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED 1/

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES 2/ MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	3.50	7.95	2.27	141.1	24,805
50-100	1.09	5.32	4.88	44.0	24,773
100-150	0.21	1.38	6.57	8.2	25,610
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
TOTAL	4.80	TOTAL 14.65	AVERAGE 3/ 3.05	TOTAL 193.3	

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 14.0 feet.

2/ Sawyer Coal has been burned or eroded away in 40 percent (127.7 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 17

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 6, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED [1/]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2/] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0	0	---	0	---
50-100	0	0	---	0	---
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
	TOTAL 0	TOTAL 0	AVERAGE [3/] ---	TOTAL 0	

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 0 feet.

2/ Sawyer Coal has been burned or eroded away in 100 percent (683.4 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 18

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD, MONTANA
SECTION 8, T. 3 S., R. 45 E.

COAL RESERVES, OVERBURDEN VOLUMES AND RATIOS,
ACRES AND TONS PER ACRE
SAWYER COALBED [1]

THICKNESS OF OVERBURDEN (FT.)	MEASURED AND INDICATED RESERVES [2] MILLION TONS	OVERBURDEN MILLION CUBIC YARDS	OVERBURDEN RATIO CUBIC YARDS PER TON	ACRES	TONS PER ACRE
0-50	0.78	0.57	0.73	29.4	26,531
50-100	0	0	---	0	---
100-150	0	0	---	0	---
150-200	0	0	---	0	---
Over 200	0	0	---	0	---
	TOTAL 0.78	TOTAL 0.57	AVERAGE [3] 0.73	TOTAL 29.4	

FOOTNOTES:

1/ Thickness of Sawyer Coalbed in this section averages 15.0 feet.

2/ Sawyer Coal has been burned or eroded away in 95 percent (610.6 acres) of this section.

3/ Average shown is a weighted average based on the number of acres per individual ratio.

ENGLISH TO METRIC CONVERSIONS

MULTIPLY	BY	TO OBTAIN
Foot	0.3048	Meter
Acre	0.4047	Hectare
Ton	0.9072	Tonne
Cubic Yard	0.7646	Cubic Meter

NOTE

Thickness of coal, overburden, and interburden based on data from Intrasearch, U.S.G.S., and Montana Bureau of Mines and Geology drill holes as shown on Plate 26.

Overburden volumes and ratios includes interburden and coalbeds younger than the Sawyer.

Table 19

APPENDIX D
SOIL AND OVERBURDEN

Sec. 4 T 3S-R 45E.

2000' S and 200' E of NW corner. 2-4% (complex), alluvial/colluvial bottom. A1: 0-4", B2t: 4-12" (m2pr/m2ebk), B3ca: 12-30"(m1pr/m1sbk), C1ca: 30-48", C2: 48-72", C3: 72-120". Salts visible at 96" +.

500' S and 100' E of NW corner. 2-4% (complex), sideslope. A1: 0-4", B2t: 4-12" (m2pr/m2ebk), B3: 12-18" (m1pr/m1sbk) C1ca: 18-30", C2: 30-48", C3: 48-66", C4cr: 66-96", R: 96" +. Thin lignite seam at 72". 48-66" zone = SAR = 15.0.

1700' W and 400' S of Sec. 2-4% (complex), colluvial sideslope. A1: 0-3", B2: 3-9" (m2pr/m2abk), B3ca: 9-12", C1ca: 12-36", C2cr: 36-96", C3: 96-120". Baked shale fragments from 108" +. 72-96" zone - SAR = 9.0, Gyp. Req. = -10.1.

1750' S and 550' E of NW corner. 2-4% (complex), footslope below shale crests. A1: 0-3", B21: 3-9" (m2pr/m2ebk), B22t: 9-18" (m2pr/m2ebk), B3ca: 18-30", C1ca: 30-48", C2: 48-72", C3: 72-96", C4: 96-120". Baked shale fragments at 72" +.

950' W and 650' S of NW. 2-4% (complex), footslope below shale crests. A1: 0-4", B21: 4-12" (m2pr/m2ebk), B22t: 12-24" (c2pr/m2abk), B3: 24-36" C1ca: 36-48", C2: 48-96", C3: 96-120". Grassed micro-depressions in unit.

500' W and 150' S of Sec. 2-6% (complex), bench remnant, slick spots in unit (50% surface cover). A1: 0-5", B21: 5-9" (c2pr/m2sbk), B22: 9-12" (c1pr/c1sbk), B3ca: 12-24", C1ca: 24-42", C2cr: 42-66" +. Strong sodium influence-dense profile. 12-24" zone - SAR = 23.0, Gyp. Req. = + 2.3.

1500' N and 1200' E of SW corner. 2-6% (complex), footslope below shale crests. A1: 0-4", B1: 4-6", B2: 6-18" (m2pr/m2abk), B3ca: 18-24", C1ca: 24-48", C2: 48-66", C3cr: 66" +. 24-48" zone - SAR = 7.0, Gyp. Req. = + 4.1. Lab text. 0-12" - SCL.

Sec. 8 T 3S-R 45E.

1050' W and 50' N of Sec. 2-4% (complex), bench remnant. A1: 0-4", B2: 4-9" (c2pr/m2abk), B3ca: 9-12" (c1pr/m1atbk), C1ca: 12-36", C2: 36-60", C3cr: 60-84" (soft sandy shale), C4cr: 84-120" (weathered shales). 12-36" zone - SAR = 5.7.

1500' E and 400' S of Sec. 2-4% (complex), bench remnant. A1: 0-3", B2: 3-12" (m2pr/m2abk), C1ca: 12-24", C2: 24-102", C3cr: 102-120" +. 48-66" zone-SAR = 12.0, Gyp. Req. = + 1.4.

1250' N and 1200' E of Sec. 2-4% (complex), sideslope - baked rock outcrops in unit. A1: 0-3", B21: 3-7" (c1pr/m1abk), B22: 7-12" (m2pr/m2abk), B3: 12-18", C1ca: 18-42", C2: 42-66", R: 66 " +. 42-66" zone - SAR = 16.0, Gyp. req. = 13.0.

1200' S and 1000' E of Sec. 2-4% (complex), sideslope - baked rock outcrops in unit. A1: 0-3", B2: 3-12" (m2pr/m2abk), B3ca: 12-16", C1ca: 16-30", C2: 30-48", C3: 48-66", C4cr: 66 + (weathered sandstone).

700' W and 200' S of NE corner. 2-4% (complex), colluvial swale below shale/sandstone crests. A1: 0-2", B2t: 2-12" (m2pr/m2abk), B3ca: 12-16", C1ca: 16-24", C2: 24-72", C3cr: 72-90", R: 90" + (shale). 12-24" zone - SAR = 8.6, Cyp. Req. = + 9.2

1550' W and 400' N of SE corner. 0-2% (complex), alluvial/colluvial bench remnant. A1: 0-4", B21t: 4-12" (m2pr/m2sbk), B22t: 12-30" (m2pr/m2sbk), B3ca: 30-36", C1ca: 36-54", C2: 54-84", C3: 84-108", C4cr: 108" + (loamy gray shale w/carbonaceous influence). B4-102" zone - SAR = 10.0, Gyp. Req. = + 1.1.

1250' E of Sec. 2-4% (complex), bench remnant. A1: 0-4", B2t: 4-18" (m2pr/m2abk), C1ca: 18-36" C2: 36-78", C3cr: 78" + (weathered baked shale). 90-102" zone - SAR = 7.4, Cyp. Req. = + 2.8.

200' N of Sec. 2-4% (complex), sideslope, w/slick spots in unit. A1: 0-3", B2t: 3-12" (m1cpr/m1abk), B3ca: 12-15", C1ca: 15-30", C2cr: 30-48", R: 48" + (sandy shales - semi-consolidated). 30-48": S = 8.7%, Si = 78.1%, C = 13.2% (SiL).

1300' E and 900" N of Sec. 2-4% (complex), colluvial sideslope - baked rock outcrops in unit. A1: 0-3", B2: 3-12" (m2pr/-m2ebk), B3ca: 12-15", C1ca: 15-36", C2: 36-96", C3: 96-120". Underlying bedrock near 120".

1600' E and 1100' S of NW corner. 2-4% (complex), alluvial colluvial footslope. A1: 0-3", B21: 3-7" (c1pr/m1abk), B22: 7-12" (m2pr/m2abk), B3: 12-18", C1ca: 18-42", C2: 42-66", R:66 " +. 42-66" zone - SAR = 16.0, Gyp. req. = 13.0.

1300' N and 350" E of SW corner. Shallow soils over shale/sandstone. Deeper soils in unit occur in narrow drainages - too small to delineate.

800' N and 600' W of Sec. 2-4% (complex), bench remnant. A1: 0-4", B2: 4-12" (c2pr/m1abk), B3ca: 12-15", C1ca: 15-36", C2: 36-66", C3cr: 66-84" (sandy shale) C4cr: 84-120" (sandy shale). Slick spots occur in unit.

850' N and 400' W of Sec. 0-2% (complex), alluvial/colluvial bottomland. A1: 0-2", B21: 2-6" (c1pr/m1sbk), B22t: 6-14" (m2pr/m2sbk), B3: 14-36" (c1pr/m1abk), C1: 36-84", C2cr: 84-104", C3cr: 104-120". 84" + soft sandy shales.

2200' E and 1100' S of NW corner. 0-2% (complex), alluvial bottom - Cook Cr. A1: 0-2", B21: 2-6" (c1pr/c1abk), B22: 6-24" (m1pr/m1abk), C1: 24-48", C2: 48" + (stratified FSL and gravelly layers). Channel cut shows material depth exceeds 10'.

450' N and 300' E of SW corner. 2-6% (complex), sideslope. 40% of unit has slick spots. A1: 0-1", AB: 1-5", B2t: 5-9" (m2cpr/m2ebk), B3: 9-18", C1cr: 18-60", R: 60" + (shale). 18-42" zone - Gyp. Req. = -5.3, lab texture - SiL.

2050' E and 200' S of Sec. 0-2% (complex), alluvial/colluvial bottom. A1: 0-4", B21: 4-12" (c2pr/m2abk), B22: 12-24" (c2pr/m2abk), B3ca: 24-30" C1ca: 30-48", C2: 48-96", C4: 96-120". Grassed micro-depressions in unit.

900' S and 100' W of Sec. 2-4% (complex), swale below shale outcrops. A1: 0-4", B21: 4-8" (m1pr/m1abk), B22: 8-12" (m2pr/m2abk), C1cr: 12-30" (weathered shale), IIC2cr: 30-48" (soft sandstone). R: 48" +. 30-48" zone - SAR = 10.0.

1300' E and 50' N of SW corner. 2-4% (complex), alluvial/colluvial fan. A1: 0-3" B2: 3-12" (m2pr/m2obk), B3: 12-18" (m2pr/m2abk), C1ca: 18-36", C2: 36-66", C3cr: 66-114", R: 114" + (baked rock) 66-90" - SAR = 5.0, Gyp. Req. = + 0.6.

1250' N and 400' W of Sec. 2-4% (complex), depressional basin. A1: 0-4", B21: 4-8" (m2pr/m2ebk), B22t: 8-24" (m2pr/m6f2-ebk), B3: 24-30", C1ca: 30-48", C2: 48-72", R: 72" + (sandy shale). 48-72" zone - SAR = 9.6, Cyp. Req. = + 1.8, lab texture - L.

2100' S of Sec. 0-2% (complex), depressional basin. A1: 0-3", B21: 3-9" (m2cpr/m1fabk), B22: 9-24" (c2pr/c2abk), B3ca: 24-30" (c1pr/m1abk), C1ca: 30-42", C2cr: 42-66" +.

1300' W and 350' S of Sec. 2-4% (complex), footslope below shale crests. A1: 0-3", B2: 3-12" (m2pr/m2sbk), C1cr: 12-24" (weathered shale), IIC2cr: 24-36" (soft sandstone), R: 36" + (sandstone). Deeper materials in drainage bottoms.

1100' W and 600' N of Sec. 2-4% (complex) sideslope - baked rock outcrops in unit. A1: 0-3", B2: 3-10" (m2pr/m2abk), C1ca: 10-30", C2: 30-48", C3: 48-66", R: 66" + (baked rock).

SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH

3 SOIL PROFILE NUMBER

CL — 2.8 - - 2.8 EC mmhos cm Soil Est.
B.4 - B0 — B4 pH 1:5 Soil-Water Suspension
B0 pH Soil Paste
65 Hydraulic Conductivity in/hr.
Disturbed Samples
24 Settling Volume
L1.C
Gr

65/24

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SICL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; sg-o Informative symbols
SURFACE LAYER — Quality, Depth
SECOND LAYER — Quality, Depth
GEOLOGIC MATERIAL — Quality, Depth
No of Acres
Divides soil material and geologic material

INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)
- b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

- g Slope (including gradient and complexity)
- r Exposed bedrock (outcrops)

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo, slick or scabby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock (scoria) outcrop
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

1: 12,000

POWDER RIVER COUNTY
W/2 SECTION 4, SECTIONS 6 & 8 - T. 3 S., R. 45 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD - MONTANA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIESCHEL — FIELD APPROVAL
DRAWN L.E. ALLSOP — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1982 — 1305-600-304

(1) Sec. 29 T2S-R45E

300' E and 200' N of Sh. 0-2% (complex), bench remnant. A1: 0-2", B21: 2-10" (mlpr/mlabk), B22: 10-15" (m2pr/m2abk), B3ca: 15-24", C1ca: 24-48", C2: 48-96", C3: 96-120" +.

(1) Sec. 30 T2S.-R45E.

2400' E and 300' S of Wh. 2-8 % (complex), side slope. A1: 0-1", B21: 1-7" (m2pr/m2abk), B22t: 7-16" (m2pr/m2abk), B3ca: 16-30", C1cs: 30-48", C2: 48-84", R: 84" +. Profile crusty-hard sugering. Profile better than avg. for unit. Shallow sites have .0-0.5' of material.

(7) 1100' W and 100' N of SE corner. 0-2% (complex), bench remnant. A1: 0-3", B21: 3-15" (m2pr/m2abk), B22: 15-24" (m2pr/m2abk) B3ca: 24-33", C1ca: 33-51", C2: 51-96", C3: 96-120"+. SAR = 6.6 - 36-54", SAR = 7.3 - 96-120".

(3) 1000' N and 400' E of Sh. 0-2% (complex), alluvial/colluvial bottom. Cultivated. Ap: 0-4", B2: 4-12" (m2pr/m2abk), B3: 12-24", C1cs: 24-48", C2: 48-72", C3: 72-96", 96" + sandstone.

(9) 1200' W and 600' S of NE corner. 2-4% (complex), footslope below sandy shale crest. A1: 0-4", B2: 4-8" (m2cpr/m2abk), B3ca: 8-15", C1ca: 15-30", C2ca: 30-54", C3: 54-120". Strong sodium influence throughout profile.

(13) 1050' S and 350' E of Wh.

Refer to Point Site Profile description in Appendix D.

(2) 1100' S and 700' W of Eh. 0-2% (complex), bench remnant below shale crest. A1: 0-2", B21: 2-7" (mlpr/mlabk), B22: 7-15" (m2pr/m2abk), C1cs: 15-36", C2: 36-60", C3: 60-84", C4: 84-108", C5: 108-120", Old AP: 0-7".

(2) 1800' E and 200' N of Wh. 2-8 % (complex), bench remnant. A1: 0-6", C1ca: 6-24", C2: 24-72", C3: 72-108" R: 108" +. Profile located near crest - shallower profiles occur on slopes.

(8) 300' S and 300' W of NE corner. 2-4% (complex), dissected uplands-shale outcroppings in unit. A1: 0-2", B2: 2-12" (mlpr/mlabk), C1ca: 12-24", C2cr: 24-48", R: 48" + (sandstone). 12-48" alightly sroative. Depth of topsoiling material varies from 6-18".

(4) 1300' N and 1100' W of SE corner. 2 4% (complex), foot slope beneath shale/sandstone crests. A1: 0-3", B2: 3-12" (m2cpr/m2abk), B3: 12-15", C1ca: 15-42" R: 42" + (shale). Sodium - influenced profile.

(10) 1100' W and 500' N of Eh. 2-4% (complex) bench remnant. A1: 0-4", B2: 4-12" (m2pr/m2abk), B3: 12-15", C1ca: 15-36", C2: 36-96", R: 96" + (baked shale). Baked rock outcrops in unit. 36-54" zone - SAR = 13.0.

(3) 400' W and 300' N of Sh. 6-15% (complex), sidesalops with scattered baked rock surface fragments. A1: 0-2", B2: 2-12" (m2pr/m2abk), C1ca: 12-24" C2: 24-48", C3: 48-60", R: 60" + (sandstone). Profiles shallower on steep slopes. 12-24" zone - SAR = 13.0, Gyp. Req. = + 4.7.

(9) 1000' W and 400' E of Sh. 0-2% (complex) colluvial bench. A1: 0-4", AC: 4-7", C1ca: 7-24", C2: 24-48", C3: 48-108", C4: 108-120". Some profiles shallower over bedrock in unit. SAR - 11.0 in 66-84" zone.

(5) 1250' W and 1100' S of Eh.

Refer to Point Site Profile description in Appendix D.

(5) 1000' S and 800' W of Eh. 2-4% (complex), colluvial footslope. A1: 0-2", AB: 2-8", B2: 8-12" (m2cpr/m2abk), B3ca: 12-21", C1ca: 21-42", C2: 42-66", R: 66" + (shale).

(11) 900' W and 600' S of Nh. 0-2% (complex), bench remnant. A1: 0-5", B2: 5-18" (m2pr/m2abk), C1ca: 18-30", C2: 30-84", C3cr: 84" + (weathered sandstone)

(4) 1900' E and 200' S of Wh. 2-4% (complex), footslope. A1: 0-2", B21: 2-12" (mlpc/mlabk), C1ca: 12-36", C2: 36-90", R: 90" +. Salt crystals visible at 84" +.

(4) 1050' E and 1000' S of Wh. 2-6% (complex), colluvial sideslope/swale. A1: 0-2", B2: 2-8" (m2pr/m2abk), B3: 8-12", C1ca: 12-30", C2: 30-72", C3: 72-90", R: 90" +. Some profiles on slopes shallower in unit. 30-48" zone - SAR = 15.0, Gyp. Req. = + 7.8

(10) 1050' N and 950' E of NE corner.

Refer to Point Site Profile description in Appendix D

(6) 1000' N and 300' W of Eh. 0-2% (complex), alluvial/colluvial bottom below shale creats. A1: 0-3", B2t: 3-18", (mlcpr/mlabk), B3ca: 18-24", C1ca: 24-42", C2: 42-96", C3: 96-120". Baked shale influence -96" + 0-18" zone- SAR = 9.6.

(12) 1250' S and 125' E of SW corner.

Refer to Point Site Profile description in Appendix D.

(5) 1300' N and 1150' E of SW corner. 2-4% (complex), bench remnant. A1: 0-2", B21: 2-7" (m2pr/m2abk), B22: 7-12" (m2pr/m2abk), B3: 12-18", C1ca: 18-42", C2: 42-36", C3: 56-72", R: 72" + (sandstone).

(5) 900' N and 100' E of SW corner. 2-4% (complex), alluvial/colluvial bench remnant. A1: 0-3", B2: 3-12", B3ca: 12-18", C1ca: 18-30", C2: 30-78", C3: 78-120". Shallower profiles exist on slopes within unit.

(1) Sec. 32 T2S.-R45E.

900' N and 100' E of Wh. 0-2% (complex), bench remnant. A1: 0-2", B21: 2-6" (mlpr/mlabk), B22: 6-12" (m2pr/m2abk), B3ca: 12-15", C1ca: 15-36", C2: 36-60", C3: 60-78", 78" + hard sandstone.

(7) 800' W and 100' S of Eh. 0-2% (complex), alluvial/colluvial bottom. A1: 0-3", B2: 3-12" (m2pr/m2abk), B3: 12-18", C1ca: 18-42", C2: 42-72", C3: 72-96", C4: 96-120". 42-54" zone - SAR = 22.0, Gyp. Req. = + 8.3.

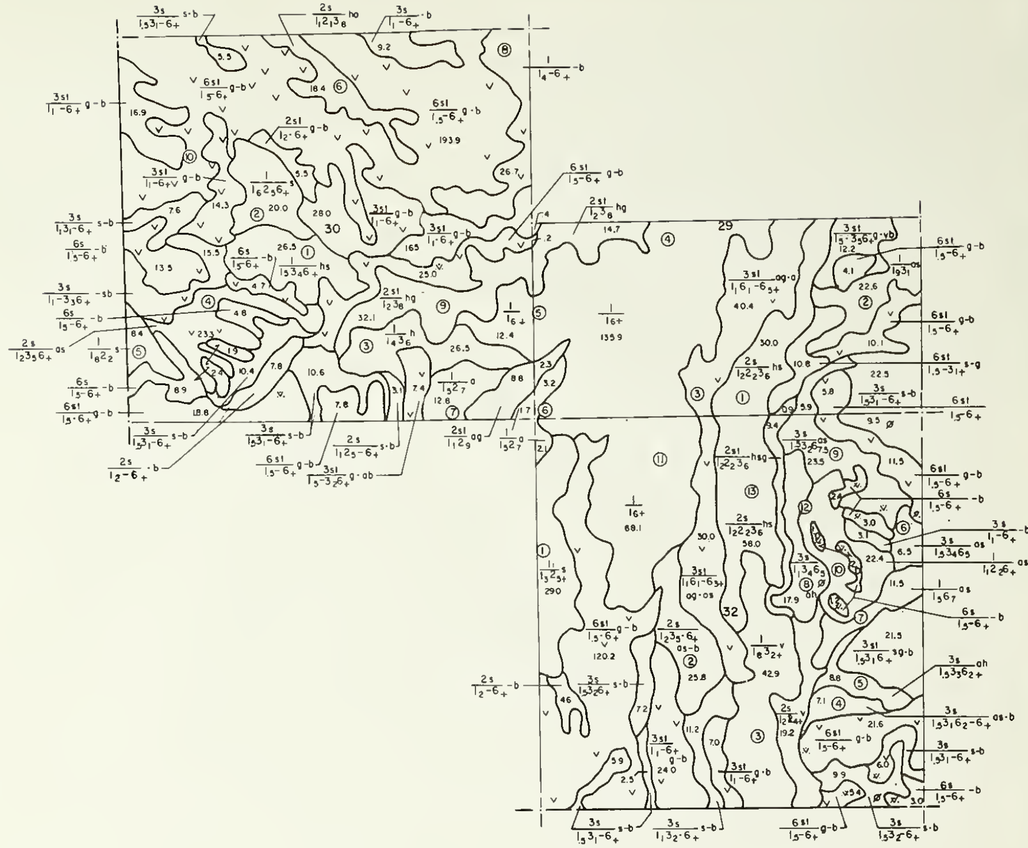
(6) 125' N and 125' E of SW corner.

Refer to Point Site Profile description in Appendix D.

(6) 750' S and 400' E of Wh. 2-6% (complex), sidesalops above drainage. A1: 0-2", B2: 2-12", B3ca: 12-18", C1ca: 18-48", C2: 48-120" +. SAR = 11.0 - 48-72"; SAR = 12.0 - 96-120", Gyp. Req. = + 2.8.

(2) 2000' N and 500' W of Wh. 0-2% (complex), bench remnant. A1: 0-4", B21: 4-8" (m2pr/m2abk), B22t: 8-18" (m2pr/m6f2abk) B3: 18-24", C1ca: 24-42", C2: 42-66", C3: 66-84", R: 84" + (sandstone). 24-42" zone - SAR = 9.3.

(8) 1600' W and 300' N of Eh. 0-2% (complex), alluvial/colluvial bottom. Cultivated. Ap: 0-5", B2: 5-12" (m2pr/m2abk), B3ca: 12-15", C1ca: 15-36", C2ca: 36-120", influence in unit. 18-36" zone - SAR = 10.0.



SOIL PROFILE NOTES

PROFILE REPRESENTS ID' DEPTH

(3) SOIL PROFILE NUMBER

65/24 C L / L1.C / Gr

2.8--2.8 EC mmhos cm Sat.Ext.
6.4-8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Soil Paste
65 Hydraulic Conductivity in/hr Disturbed Samples
24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

LAND CLASSIFICATION SYMBOLS

LAND CLASS — Plant media deficiency; Topographic deficiency; sg-a — informative symbols

SURFACE LAYER: Quality, Depth — 2 1 3 6 — 3 5 — IDD

SECOND LAYER: Quality, Depth

GEOLOGIC MATERIAL: Quality, Depth

No of Acres

Divides soil material and geologic material

INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

a Sodicity
s Salinity
h Clay(very fine texture)
v Coarse(very sandy texture)
p Restricted permeability
q Available moisture capacity
d Depth of suitable overburden
x Cabbly,stony,flaggy or clinkers (soil profile)
b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

g Slope (including gradient and complexity)
r Exposed bedrock (outcrops)

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo,slick or scabby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock (scoria) outcrop
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

1: 12,000

POWDER RIVER COUNTY

S/2 SECTION 29, SECTIONS 30 & 32- T. 2 S., R. 45 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA-
ASHLAND COALFIELD - MONTANA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — FIELD APPROVAL
DRAWN L.E. ALLSOP — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1982 — 1305-600-305

Sec. 24 T. 2 S. - R. 44 E.

(1) 1200' W 700' N of SE corner. 2-4% (complex) alluvial/colluvial bottomland bordered by baked sandstone creste. A1: 0-3", B21: 3-7", B3ca: 7-14", C1ca: 14-28", C2: 28-42", C3: 42 +", SAR: 24-42" = 11.0. Channel cut shows 20+ or more of available material. Bluebunch wheatgrass, Silver sagebrush.

(7) 1100' S 300' E of W¼. 2-4% (complex), bench remnant. A1: 0-3", B2: 3-12" (m2pr/m2abk), B3ca: 12-17", C1ca: 17-30", C2: 30-54", C3: 54-72", R: 72" +. Common baked shale fragments in 54-72" zone.

(6) 1200' S and 950' E of NW corner. 2-4% (complex), lower sideslope adjacent to main drainage. A1: 0-2", B2: 2-9" (m2pr/m2abk), B3ca: 9-12", C1ca: 12-30", C2: 30-54", C3: 54-96", C4: 96-120". SAR: 17.0 -30- 54" zone. Sand content increases with depth.

Sec. 18 T. 2 S. - R. 45 E.

(2) 1800' W 900' S of E¼. 2-4% (complex), beach remnant. A1: 0-3", B2: 3-12" (m1pr/m1abk), C1ca: 12-24", C2: 24-96", IIC3: 96-120" + (raddish brown - scoria influence), 12-96" - slightly arosive.

(1) 300' S of W¼ 2-4% (complex), beach remnant. A1: 0-3", B2: 3-12", C1ca: 12-24", C2: 24-48", IIC3: 48-72", IIIC4-cr: 72-120" + (soft sandstone).

(7) 800' W and 300' N of S½. 2-4% (complex), alluvial/colluvial fan. A1: 0-3", B2: 3-12" (m2pr/m2abk), C1ca: 12-24", C2: 24-66", C3cr: 66-90", R: 90" + (sandstone).

Sec. 24, T. 2 S. - R. 44 E.

(3) 1000' N 700' W of E¼. 2-4% (complex), bench remnant. A1: 0-3", B1: 3-6", B2: 6-12", B3ca: 12-18", C1ca: 18-30", C2: 30-48", R: 48" +. Depth to bedrock varies within unit.

(2) 1350' N and 1000' E of SW corner. 2-4% (complex), alluvial/colluvial bottomland below sandstone creste. A1: 0-3", B2: 3-12" (m2pr/m2abk). B3ca: 12-24", C1ca: 24-42", C2: 42-56", C3: 56-102", R: 102" + (sandstone).

(8) 1700' W 450' S of E¼.

Refer to Point Site Profile description in Appendix D.

Sec. 24, T. 2 S. - R. 44 E.

(4) 2100' E 300' N of W¼. 2-4% (complex), bench remnant. A1: 0-4", B2: 4-12" (m2pr/m2ebk), B3ca: 12-24", C1ca: 24-42", C2: 42-66", R: 66 +. Avg. depth to BR is 60". 42-66" slightly erosive.

(3) 1900' E and 400' N of W¼. 2-4% (complex) alluvial/colluvial bottomland below sandstone creste. Profile not logged.

(9) 1050' E, 50' N of SW corner.

Refer to Point Site Profile description in Appendix D.

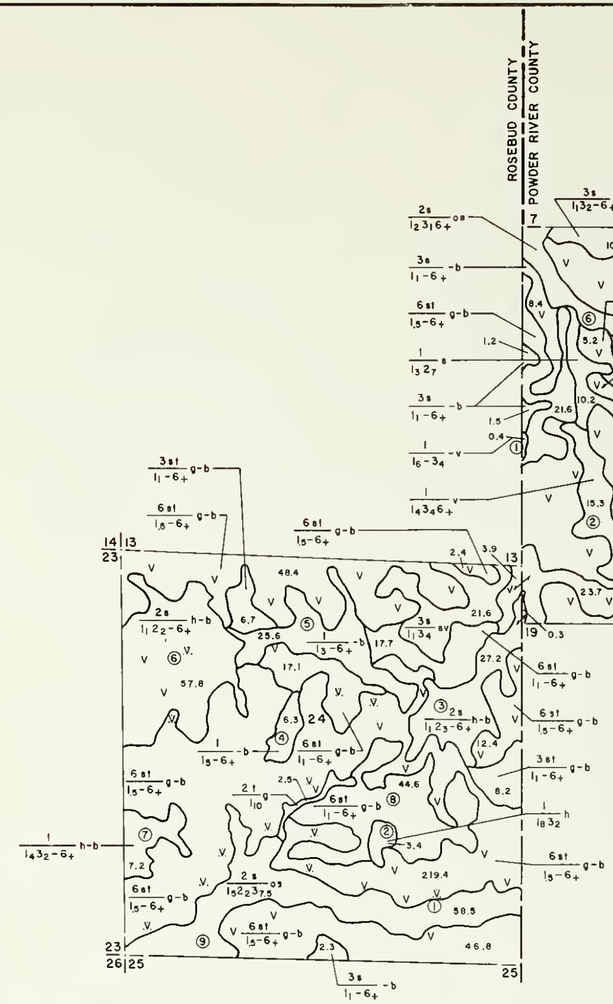
(5) 900' S 200' W of N¼. 2-6% (complex) bench remnant. A1: 0-3", B21: 3-10" (c1pr/m1abk), B22: 10-18" (c1abk/m1ebk) B3: 18-24", C1ca: 24-36", R: 36" + (sandstone).

(4) 900' S and 300' W of E¼. 2-4% (complex) alluvial/colluvial bottomland. A1: 0-3", B2: 3-15", (m2pr/f2abk), C1ca: 15-30", C2: 30-120" +. Sand content increases with depth.

(6) 1400' S 700' E of NW corner. 2-4% (complex), bench remnant. A1: 0-4", AB: 4-6", C1ca: 6-36", R: 36" +. Numerous baked rock fragments - 6-36". Baked shale outcrops in unit.

(5) 1600' W and 1000' S of E¼. 2-4% (complex), alluvial/colluvial bottomland. A1: 0-3", B2: 3-18" (m1pr/m1abk), B3ca: 18-24", C1ca: 24-36", C2: 36-72", C3: 72-96", C4: 96-120" +.

ROSEBUD COUNTY
POWDER RIVER COUNTY



SOIL PROFILE NOTES

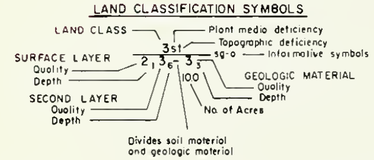
PROFILE REPRESENTS 10' DEPTH

(3) SOIL PROFILE NUMBER

CL / LIC / Gr

2.8 -- 2.8 EC mmhos cm Sat Ext
8.4 - 8.0 8.4 pH 1:5 Soil - Water Suspension
8.0 pH Soil Paste
65 Hydraulic Conductivity in/hr
Disturbed Samples
24 Settling Volume

LAND CLASSIFICATION SYMBOLS



SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Cobbly, stony, flaggy or clinkers (soil profile)
- b Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

- g Slope (including gradient and complexity)
- t Exposed bedrock (outcrops)
- c Cover (trees)

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly Cobbly spot
- Gumbo, slick or scabby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock (scoria) outcrop
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

1: 12,000

POWDER RIVER COUNTY
SECTION 18, T.2S., R.45E.

ROSEBUD COUNTY
SECTION 24, T.2S. R.44E.

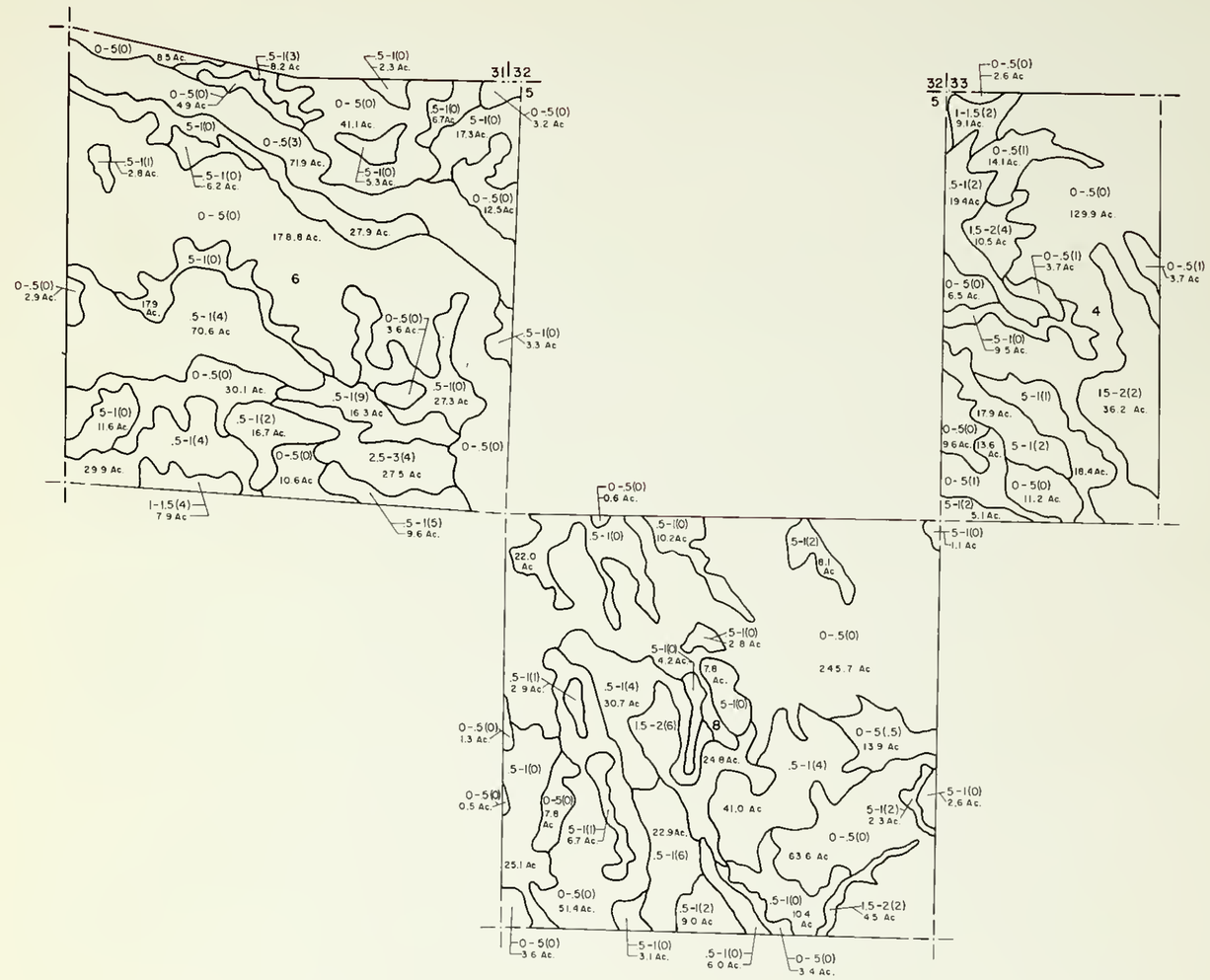
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD - MONTANA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED T. FIECHTL — FIELD APPROVAL
DRAWN R. GILSON — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — FEBRUARY, 1982 — 1305-600-306



EXPLANATION

* DEPTH (FT.) OF PREFERRED MATERIAL — ** DEPTH (FT.) OF ACCEPTABLE MATERIAL

.5-1 (1)

25.0 Ac. – ACREAGE

NOTES:

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonacidic, and permeable.

**Acceptable material refers to additional good quality material immediately below the preferred material. This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material. In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil.

POWDER RIVER COUNTY

W/2 SECTION 4, SECTIONS 6 8 8 – T. 3 S., R. 45 E.

1 : 12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD – MONTANA

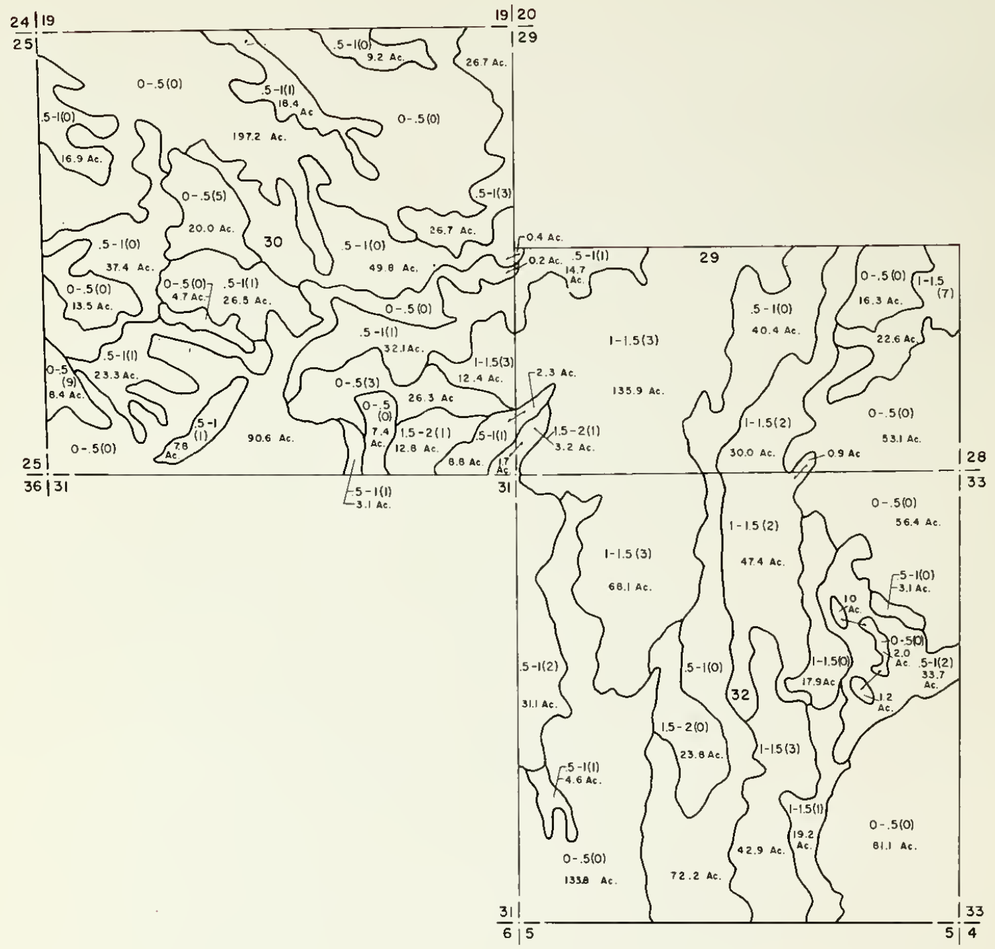
TOPSOILING MATERIAL

LANDS T. FIECHTL — FIELD APPROVAL

DRAWN R. OILSON — TECHNICAL APPROVAL

CHECKED — APPROVED

BILLINGS, MONTANA — MARCH, 1982 — 1305-600-307



EXPLANATION

DEPTH (FT.) OF PREFERRED MATERIAL* — DEPTH (FT.) OF ACCEPTABLE MATERIAL**

.5-1 (1)

25.0 Ac. - ACREAGE

NOTES:

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonsodic, and permeable.

**Acceptable material refers to additional good quality material immediately below the preferred material. This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material. In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil.

POWDER RIVER COUNTY

S/2 SECTION 29, SECTIONS 30 & 32, T. 2 S., R. 45 E.

1" = 2,000'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

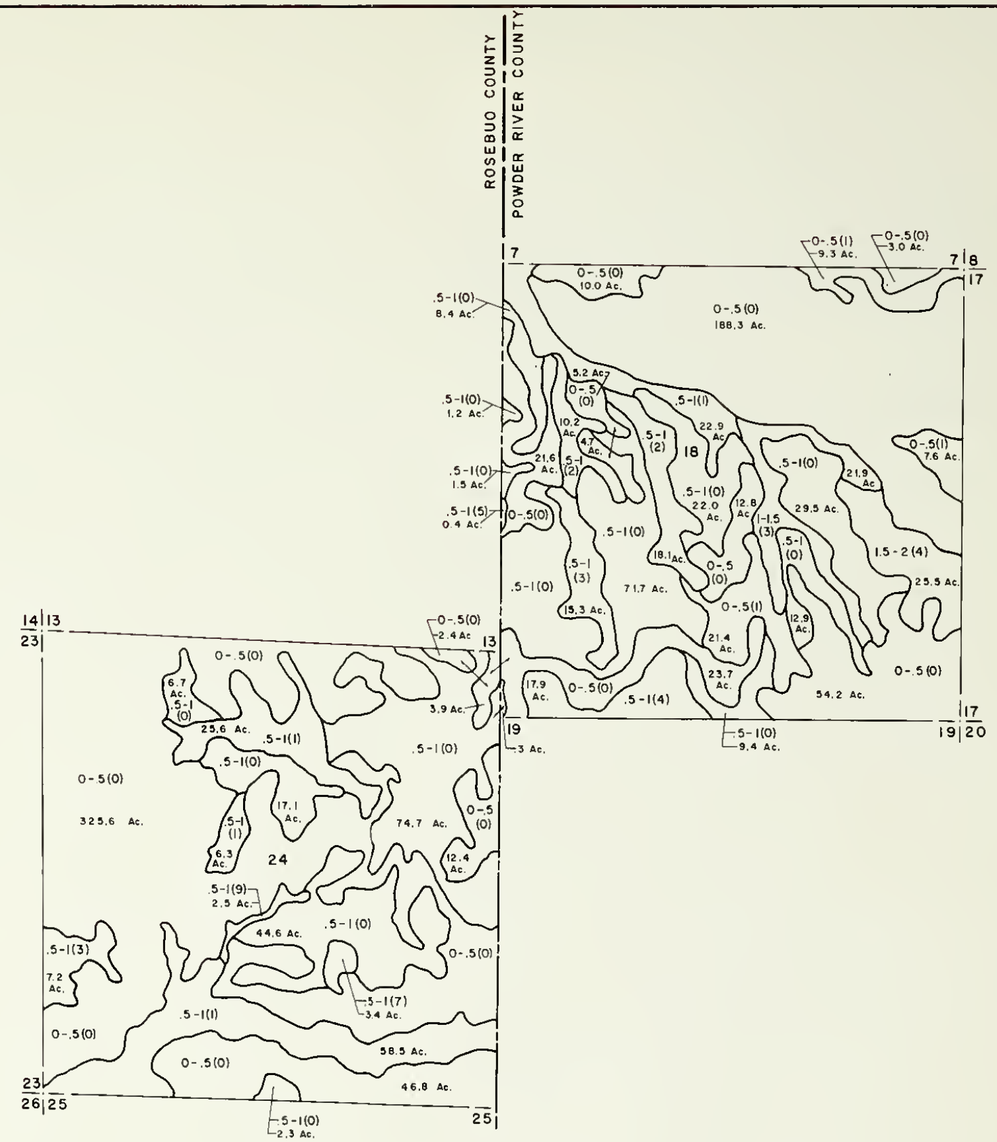
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD - MONTANA

TOPSOILING MATERIAL

LANDS T. FIECHTL	FIELD APPROVAL
DRAWN R. GILSON	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA	MARCH, 1982

1305-600-308



EXPLANATION

DEPTH (FT.) OF PREFERRED MATERIAL* — DEPTH (FT.) OF ACCEPTABLE MATERIAL**

.5-1 (1)

25.0 Ac. – ACREAGE

NOTES

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is noncaline, nonsodic, and permeable.

**Acceptable material refers to additional good quality material immediately below the preferred material. This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material. In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil.

POWDER RIVER COUNTY
SECTION 18, T.2S., R.45E.

ROSEBUD COUNTY
SECTION 24, T.2S., R.44E.

1 : 12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

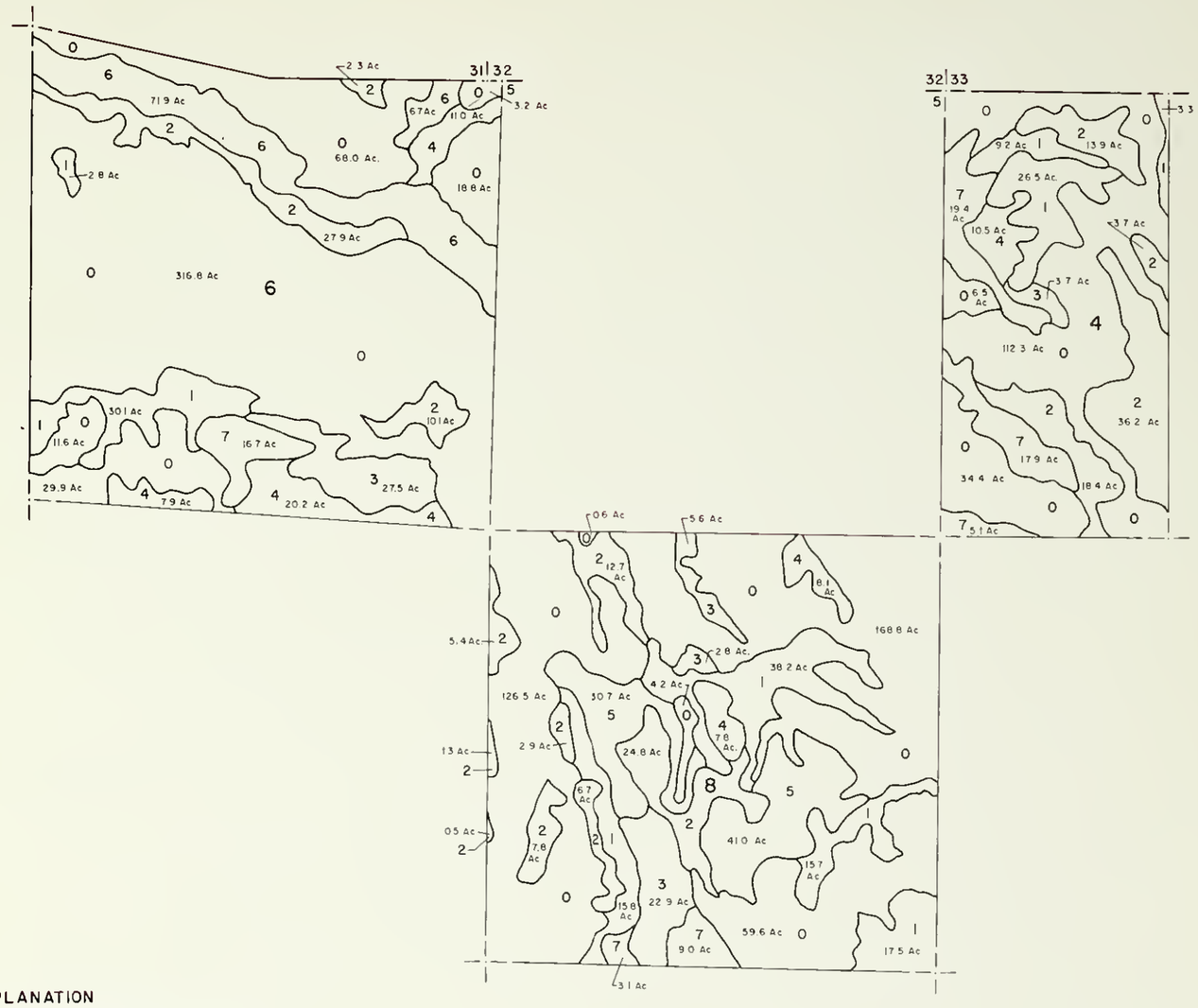
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD – MONTANA

TOPSOILING MATERIAL

LANDS T. FIECHTL — FIELD APPROVAL
DRAWN R. GILSON — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA APRIL, 1982 | 1305-600-309



EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2/

1/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE:
Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

POWDER RIVER COUNTY
W/2 SECTION 4, SECTIONS 6 & 8 — T. 3 S., R. 45 E.

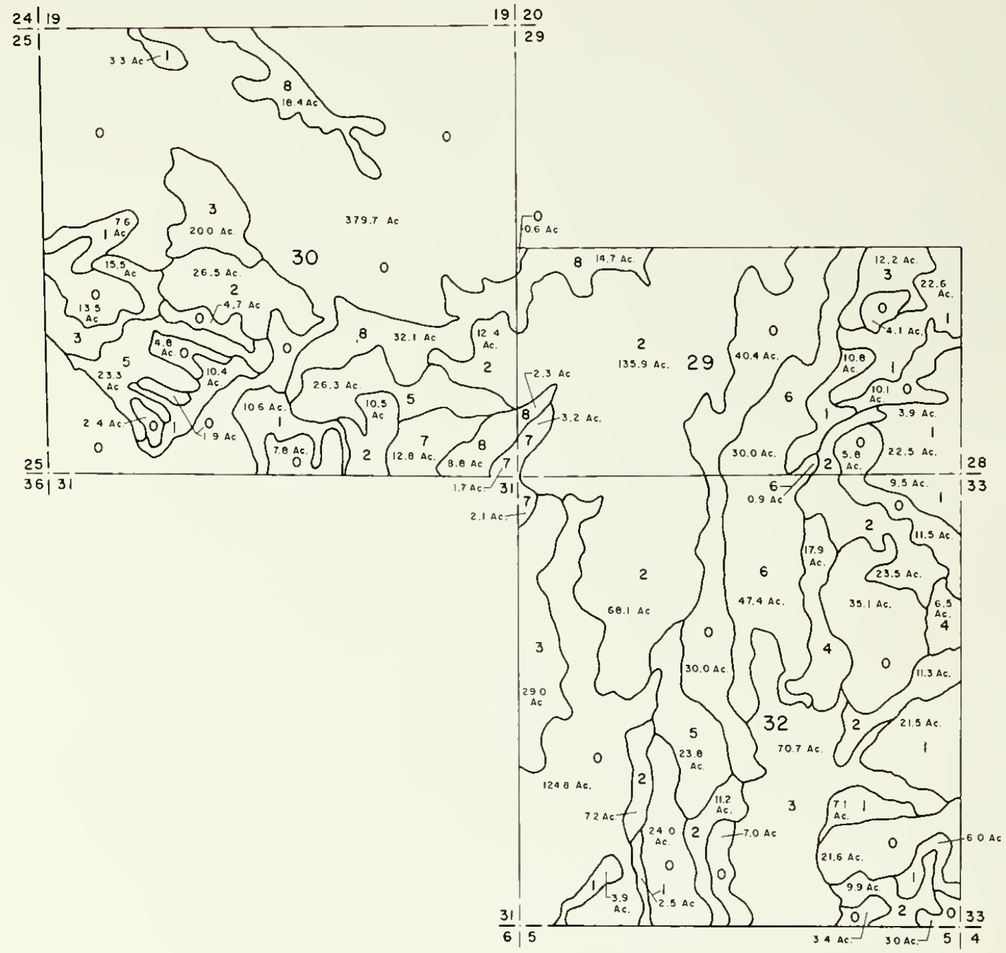
1 : 12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD — MONTANA

SUBSURFACE MATERIAL

LANDS T. FIECHTL	FIELD APPROVAL
DRAWN R. GILSON	TECHNICAL APPROVAL
CHECKED	APPROVED
BILLINGS, MONTANA — FEBRUARY, 1982	1305-600-310



EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2/

1/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

POWDER RIVER COUNTY
S/2 SECTION 29, SECTIONS 30 & 32, T.2S., R.45E.

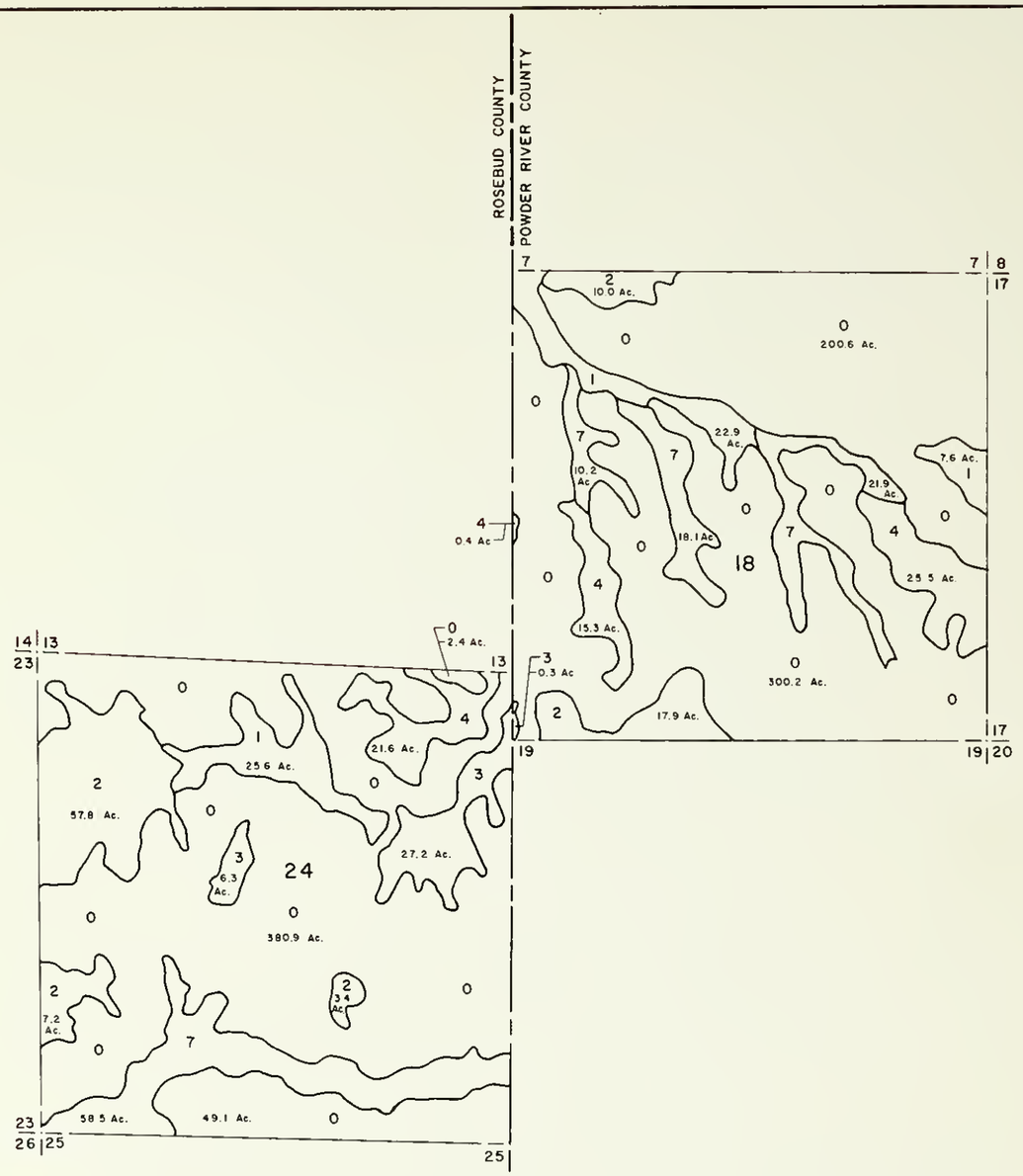
1 : 12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD – MONTANA

SUBSURFACE MATERIAL

LANDS	T. FIECHTL	FIELD APPROVAL	
DRAWN	R. GILSON	TECHNICAL APPROVAL	
CHECKED		APPROVED	

BILLINGS, MONTANA — MARCH, 1982 — 1305-600-311



EXPLANATION

QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2/

1/ ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE:

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles. This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated. It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc.

POWDER RIVER COUNTY
SECTION 18, T.2S., R.45E.

ROSEBUD COUNTY
SECTION 24, T.2S., R.44E.

1" = 12,000

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

COOK MOUNTAIN STUDY AREA
ASHLAND COALFIELD MONTANA

SUBSURFACE MATERIAL

LANDS T. FIECHTL FIELD APPROVAL
DRAWN R. GILSON TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA APRIL, 1982

1305-600-312

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 24 Twp. 2 S. Range 44 E.
1700' W. and 450' S. of E¼
Climate: Continental; semi-arid
Land Use: Forestland/Rangeland
Point Site Number: 8

Relief: Complex; convex
Elevation: 3280 Ft
Slope: Aspect: 4%, N-NE
Vegetation: Ponderosa pine, Little Bluestem
Erosion: Slight

Stoniness:
Drainage: Excessively well drained
Ground Water:
Land Form: Sedimentary uplands

Parent Material: Sandstone-Tongue River Member
Soil Series: Vebar
Soil Classification: Coarse-loamy, mixed, Typic Haploboroll
Profile Description By: W. Volk Date 1/83
Correlated By: W. Volk Date 1/83

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
V - 32 21,132	0.0-3.0	A11	Grayish brown (10YR 5/2) fine sandy loam; very dark gray (10YR 3/1) moist; single grain structure; loose; nonsticky; nonplastic; noneffervescent; abrupt wavy boundary.
V - 33 21,133	3.0-5.0	A12	Dark grayish brown (10YR 4/2) fine sandy loam; very dark grayish brown (10YR 3/2) moist; weak medium granular structure; loose; nonsticky; nonplastic; noneffervescent; abrupt wavy boundary.
V - 34 21,134	5.0-9.0	B21	Yellowish brown (10YR 5/4) fine sandy loam; brown (10YR 5/3) moist; moderate medium prismatic structure breaks to weak medium angular blocky; soft; very friable; nonsticky; nonplastic; non-effervescent; clear wavy boundary.
V - 35 21,135	9.0-13.0	B22	Yellowish brown (10YR 5/4) fine sandy loam, brown (10YR 5/3) moist; weak medium angular structure parts to weak medium granular; soft; very friable; nonsticky; nonplastic; noneffervescent; clear wavy boundary.
V - 36 21,136	13.0-19.0	B3k	Light yellowish brown (10YR 6/4) fine sandy loam, pale brown (10YR 6/3) moist; massive; loose; very friable; nonsticky; nonplastic; slight effervescence; gradual irregular boundary.
V - 37 21,137	19.0-34.0	C1k	Very pale brown (10YR 7/3) fine sandy loam; light yellowish brown (10YR 6/4) massive; loose; very friable; nonsticky; nonplastic; strong effervescence; gradual irregular boundary.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		21,132	21,133	21,134	21,135	21,136	21,137
DEPTH	(in)	0.0-3.0	3.0-5.0	5.0-9.0	9.0-13.0	13.0-19.0	19.0-34.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)	1.3	1.0	1.0	0.6	0.8	0.4
Coarse Sand	(1.0-0.5mm)	2.2	1.3	0.9	0.8	1.0	0.7
Medium Sand	(0.5-0.25mm)	4.5	3.8	3.4	3.6	3.3	4.1
Fine Sand	(0.25-0.10mm)	54.6	54.0	57.1	58.9	56.1	56.1
Very Fine Sand	(0.10-0.05mm)	12.3	13.0	12.3	12.6	11.8	13.7
Total Sand	(2.0-0.05mm)	74.9	73.1	74.7	76.5	73.0	75.0
Silt	(0.05-0.002mm)	16.3	16.2	12.3	11.0	12.8	13.2
Clay	(<0.002mm)	8.8	10.7	13.0	12.5	14.2	11.8
TEXTURAL CLASS (LAB.)		FSL	FSL	FSL	FSL	FSL	FSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr				2.24	3.15	1.02	0.97
24th hr		1.57	1.48	2.13	2.52	1.02	0.89
SETTLING VOLUME	(ml)	19	20	18	18	18	17
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		5.7	6.2	6.6	6.1	7.6	6.3
SOIL REACTION-pH							
Paste							
1:5 H_2O		6.9	6.9	6.9	6.8	8.8	9.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.45	-0.75	-0.71	-0.31	-1.7	-0.68
SATURATION EXTRACT							
Saturation Percentage		32.1	33.7	33.7	30.9	34.0	32.4
EC_e @ 25°C	(mmhos/cm)	0.87	0.44	0.28	0.24	0.36	0.30
Ca^{++}	(me/l)	5.76	3.02	2.20	1.98	3.18	2.52
Mg^{++}	(me/l)	2.44	1.09	0.72	0.63	0.72	0.63
Na^{+}	(me/l)	0.43	0.24	0.24	0.19	0.24	0.24
K^{+}	(me/l)	0.65	0.26	0.12	0.10	0.12	0.12
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	3.73	2.95	2.34	2.15	3.51	2.67
Cl^{-}	(me/l)	0.11	0.25	0.08	0.09	0.09	0.09
SO_4^{-}	(me/l)	2.71	1.28	0.44	0.28	0.42	0.27
NO_3^{-}	(me/l)	2.13	0.01	0.01	0.003	0.00	0.11
SAR	(me/l)	0.21	0.17	0.20	0.17	0.17	0.19
Na	(me/100g)	0.01	0.01	0.01	0.006	0.01	0.008
Ca+Mg	(me/100g)	0.26	0.14	0.10	0.08	0.13	0.10
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.099	0.039	0.028	0.031	0.088	0.092
Ca+Mg	(me/l)	0.69	0.43	0.46	0.48	1.65	1.08
EXCHANGEABLE SODIUM	(percent)	1.12	0.83	0.62	1.49	1.15	1.42
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	8.37	10.54	10.22	9.24	7.61	6.20
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 24
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 24 Twp. 2 S. Range 44 E.
1700' W. and 450' S of E¼
Climate: Continental; semi-arid
Land Use: Forestland/Rangeland
Point Site Number: 8 (con't)

Relief: Complex; convex
Elevation: 3280 Ft
Slope: Aspect: 4%, N-NE
Vegetation: Ponderosa pine, Little Bluestem
Erosion: Slight

Stoniness:
Drainage: Excessively well drained
Ground Water:
Land Form: Sedimentary uplands

Parent Material: Sandstone - Tongue River Member
Soil Series: Vebar
Soil Classification: Coarse-loamy, mixed, Typic
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
V - 38 21,138	34.0-72.0	C2cr Very pale brown (10YR 7/3) loamy fine sand; light yellowish brown (10YR 6/4) moist; massive; loose; very friable; nonsticky; nonplastic; strong effervescence; diffuse irregular boundary.
T - 31 3926	72.0-120.0	C3cr Light gray (10YR 7/2) weathered sandstone (fine sand); very pale brown (10YR 7/3) moist; slightly hard; very friable; nonsticky; nonplastic; strong effervescence.

Greenhouse Samples

T-27 - 0-5"
T-28 - 5-13"
T-29 - 13-34"
T-30 - 34-72"
T-31 - 72-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		21,138	3926
DEPTH	(in)	34.0-72.0	72.0-120.0
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0mm)	0.3	0.1
Coarse Sand	(1.0-0.5mm)	0.3	0.3
Medium Sand	(0.5-0.25mm)	0.9	4.1
Fine Sand	(0.25-0.10mm)	55.2	42.0
Very Fine Sand	(0.10-0.05mm)	25.7	17.2
Total Sand	(2.0-0.05mm)	82.4	63.7
Silt	(0.05-0.002mm)	10.5	30.1
Clay	(<0.002mm)	7.1	6.2
TEXTURAL CLASS (LAB.)		LFS	LFS
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		1.06	2.99
24th hr		1.06	
SETTLING VOLUME	(ml)	17	17
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar			7.4
15 bar		4.1	2.7
SOIL REACTION-pH			
Paste			8.6
1:5 H_2O		9.1	9.0
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)	-0.56	
SATURATION EXTRACT			
Saturation Percentage		36.1	35.0
EC_e @ 25°C	(mmhos/cm)	0.35	0.26
Ca^{++}	(me/l)	2.96	0.60
Mg^{++}	(me/l)	0.72	1.80
Na^{+}	(me/l)	0.19	0.20
K^{+}	(me/l)	0.18	0.10
CO_3^{-}	(me/l)	0.00	0.00
HCO_3^{-}	(me/l)	3.37	2.50
Cl^{-}	(me/l)	0.08	0.10
SO_4^{-}	(me/l)	0.19	0.10
NO_3^{-}	(me/l)	0.08	0.00
SAR	(me/l)	0.14	0.20
Na	(me/100g)	0.007	0.00
Ca+Mg	(me/100g)	0.13	0.10
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.09	0.10
Ca+Mg	(me/l)	1.12	1.40
EXCHANGEABLE SODIUM	(percent)	2.99	1.00
ACIDITY			
1N KCl exchange acidity			
Total	(me/100g)		
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY NaOAc@pH 8.2	(me/100g)	3.37	9.90
BORON	(mg/l)		

Table 24
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 30 Twp. 2 S. Range 45 E.
1050' N and 950' E of W¼
Climate: Continental, semi-arid
Land Use: Rangeland
Point Site Number: 10

Relief: Complex
Elevation: 3230 Ft
Slope; Aspect: 6-25% in unit, E
Vegetation: Big sagebrush, forbs
Erasian: Moderate to severe

Stoniness:
Drainage: Well drained
Ground Water:
Land Form: Dissected sedimentary uplands

Parent Material: Shale - Tongue River Member Ft. Union Formation
Soil Series: Neldore
Soil Classification: Clayey, montmorillonitic, non-acid, frigid, shallow, Ustic Torriorthent
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION		LABORATORY DESCRIPTION
				DETERMINATION
V - 29 21,129	0.0-4.0	A1	Light gray (10YR 6/1) silty clay loam; gray (10YR 5/1) moist; moderate thin platy structure; slightly hard; firm; sticky; slightly plastic; noneffervescent.	
V - 30 21,130	4.0-14.0	C1	Light gray (10 YR 6/1) silty clay loam; gray (10YR 5/1) moist; moderate thin platy structure; slightly hard; firm; slightly sticky; slightly plastic; noneffervescent; large salt crystals visible.	
V - 31 21,131	14.0-48.0+	C2cr	Light gray (10YR 7/1) weathered shale (silty clay loam); dark gray (10YR 4/1) moist; moderate thin platy structure; slightly hard; firm; slightly sticky; slightly plastic; noneffervescent.	
			Greenhouse Samples T-24 - 0-4" T-25 - 4-14" T-26 - 14-48"+	

DETERMINATION		DATA		
LABORATORY NUMBER		21,129	21,130	21,131
DEPTH	(in)	0.0-4.0	4.0-14.0	14.0-48.0
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0mm)			
Coarse Sand	(1.0-0.5mm)			
Medium Sand	(0.5-0.25mm)			
Fine Sand	(0.25-0.10mm)			
Very Fine Sand	(0.10-0.05mm)			
Total Sand	(2.0-0.05mm)	2.0	0.6	1.7
Silt	(0.05-0.002mm)	51.2	48.4	32.9
Clay	(<0.002mm)	46.8	51.0	65.4
TEXTURAL CLASS (LAB)		SiC	SiC	C
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th hr		0.09	0.04	0.04
24th hr		0.09	0.02	0.06
SETTLING VOLUME	(ml)	29	31	37
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar		23.9	26.1	26.3
15 bor		15.3	14.8	18.5
SOIL REACTION-pH				
Paste		7.8	7.6	8.3
1:5 H_2O		8.7	8.2	8.6
1:2 0.01 M $CaCl_2$				
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
$CaCO_3$ EQUIVALENT	(percent)			
GYPSUM REQUIREMENT	(me/100g)	-0.44	-4.30	-8.96
SATURATION EXTRACT				
Saturation Percentage		59.8	74.9	89.9
EC_e @ 25°C	(mmhas/cm)	0.97	5.80	8.10
Ca^{++}	(me/l)	3.62	23.71	22.40
Mg^{++}	(me/l)	5.25	53.73	90.55
No^{+}	(me/l)	2.25	15.97	27.98
K^{+}	(me/l)	0.44	0.59	0.64
CO_3^{-}	(me/l)	0.00	0.00	0.00
HCO_3^{-}	(me/l)	4.04	1.31	1.12
Cl^{-}	(me/l)	0.19	0.24	0.19
SO_4^{-}	(me/l)	7.41	93.69	139.50
NO_3^{-}	(me/l)	0.007	0.02	0.04
SAR	(me/l)	1.10	2.60	3.70
Na	(me/100g)	0.13	1.20	2.51
Ca+Mg	(me/100g)	0.53	5.80	10.15
1:5 EXTRACT				
EC_5 @ 25°C	(mmhos/cm)	0.19	3.10	3.70
Ca+Mg	(me/l)	1.30	40.93	48.55
EXCHANGEABLE SODIUM	(percent)	1.60	4.71	5.67
ACIDITY				
IN KCl exchange acidity				
Total	(me/100g)			
Al^{+++}	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	14.78	13.70	18.70
NaOAc@pH 8.2				
BORON	(mg/l)			

Table 25

GPO 833-796

7-2006A (1-76)
Bureau of Reclamation

U.S BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 32 Twp. 2 S. Range 45 E.
1050' S and 350' E of N¼
Climate: Continental, semi-arid
Land Use: Hayland
Point Site Number: 13

Relief: Single, plane
Elevation: 3280 Ft
Slope: Aspect: 1%, S
Vegetation: Alfalfa
Erosion: Slight

Staniness:
Drainage: Well drained
Ground Water:
Land Form: Low terrace - Cook Creek

Parent Material: Local alluvium/colluvium
Soil Series: Yamac
Soil Classification: Fine-loamy, mixed Borollic Camborthid
Profile Description By: W. Volk Date. 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
V - 23 21,123	0.0-8.0	Ap	Yellowish brown (10YR 5/4) silt loam; dark grayish brown (10YR 4/2) moist; very fine granular structure; soft; friable; slightly sticky; slightly plastic; noneffervescent.
V - 24 21,124	8.0-13.0	B21	Yellowish brown (10YR 5/4) clay loam; dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; hard; firm; slightly sticky; slightly plastic; noneffervescent.
V - 25 21,125	13.0-17.0	B22	Brown (10YR 5/3) clay loam; dark brown (10YR 3/3) moist; moderate fine subangular blocky structure; hard; firm; nonsticky; nonplastic; slightly effervescent.
V - 26 21,126	17.0-23.0	B3k	Pale brown (10YR 6/3) loam; brown (10YR 4/3) moist; moderate fine subangular blocky structure; very hard; firm; nonsticky; nonplastic; strongly effervescent.
V - 27 21,127	23.0-30.0	C1k	Pale brown (10YR 6/3) loam; brown (10YR 4/3) moist; massive; hard; firm; nonsticky; nonplastic; strongly effervescent.
V - 28 21,128	30.0-60.0	C2	Pale brown (10YR 6/3) clay loam; brown (10YR 5/3) moist; massive; hard; firm, slightly sticky; slightly plastic; strongly effervescent.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		21,123	21,124	21,125	21,126	21,127	21,128
DEPTH	(in)	0.0-8.0	8.0-13.0	13.0-17.0	17.0-23.0	23.0-30.0	30.0-60.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)			0.3	0.2	0.1	
Coarse Sand	(1.0-0.5 mm)			0.3	0.2	0.3	
Medium Sand	(0.5-0.25 mm)			1.7	1.3	1.3	
Fine Sand	(0.25-0.10 mm)			25.4	21.0	27.2	
Very Fine Sand	(0.10-0.05 mm)			19.0	20.0	21.4	
Total Sand	(2.0-0.05 mm)	42.9	40.4	46.7	42.7	50.3	35.4
Silt	(0.05-0.002 mm)	38.3	37.7	33.8	37.7	31.9	39.4
Clay	(< 0.002 mm)	18.8	21.9	19.5	19.6	17.8	25.2
TEXTURAL CLASS (LAB.)		L	L	L	L	L	L
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.14	0.16	0.17	0.14	0.18	0.10
24th hr		0.12	0.20	0.19	0.16	0.16	0.10
SETTLING VOLUME	(ml)	22	22	20	19	19	21
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		7.5	8.0	7.3	7.4	6.5	18.1
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.5	7.2	8.5	8.9	9.0	9.3
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)	1.25					
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+0.29	+0.19	-0.76	-0.40	-0.28	+0.33
SATURATION EXTRACT							
Saturation Percentage		39.5	37.3	40.0	37.2	36.6	37.6
EC_e @ 25°C	(mmhos/cm)	0.43	0.80	0.48	0.37	0.34	0.51
Ca^{++}	(me/l)	2.74	4.17	2.96	1.87	1.32	0.49
Mg^{++}	(me/l)	1.63	2.80	1.99	1.72	1.81	1.54
Na^{+}	(me/l)	0.29	1.29	0.38	0.43	0.53	3.59
K^{+}	(me/l)	0.39	0.18	0.14	0.12	0.10	0.11
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	4.05	3.16	4.79	2.94	2.83	3.78
Cl^{-}	(me/l)	0.11	0.17	0.17	0.18	0.17	0.44
SO_4^{-}	(me/l)	0.50	2.10	0.27	0.22	0.29	0.85
NO_3^{-}	(me/l)	0.003	2.76	0.21	0.64	0.33	0.36
SAR	(me/l)	0.19	0.69	0.24	0.32	0.42	3.60
Na	(me/100g)	0.01	0.05	0.02	0.02	0.02	0.13
Ca+Mg	(me/100g)	0.17	0.26	0.20	0.13	0.11	0.08
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.055	0.065	0.11	0.11	0.11	0.26
Ca+Mg	(me/l)	0.57	0.69	1.29	1.11	1.06	0.78
EXCHANGEABLE SODIUM	(percent)	0.34		0.92	0.92	1.32	4.52
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	14.46	15.54	12.61	11.30	9.35	10.76
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 26
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Lacation. Sec. 32 Twp. 2 S. Range 45 E.
1050' S and 350' E of N¼
Climate: Continental, semi-arid
Land Use: Hayland
Paint Site Number: 13 (con't)

Relief: Single, plane
Elevatian: 3280 Ft
Slope: Aspect: 1%, S
Vegetatian: Alfalfa
Erasion: Slight

Staniness:
Drainage: Well drained
Ground Water:
Land Farm: Low terrace - Cook Creek

Parent Material: Local alluvium/colluvium
Sail Series: Yamac
Sail Classification: Fine-loamy, mixed Borollic Camborthid
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION		LABORATORY DESCRIPTION			
				DETERMINATION		DATA	
				LABORATORY NUMBER		3917	3918
				DEPTH	(in)	60.0 - 84.0	84.0 - 120.0
T - 22 3917	60.0-84.0	C3	Not logged.	PARTICLE SIZE ANALYSIS	(percent)		
				Very Coarse Sand	(2.0-1.0mm)		
				Coarse Sand	(1.0-0.5mm)		
				Medium Sand	(0.5-0.25mm)		
				Fine Sand	(0.25-0.10mm)		
T - 23 3918	84.0-120.0	C4	Not logged.	Very Fine Sand	(0.10-0.05mm)		
				Total Sand	(2.0-0.05mm)	7.3	22.8
				Silt	(0.05-0.002mm)	61.8	49.2
				Clay	(<0.002mm)	30.9	28.0
				TEXTURAL CLASS (LAB)		SiCL	CL
				BULK DENSITY	(g/cm^3)		
		Greenhouse Samples		HYDRAULIC CONDUCTIVITY	(in/hr)		
				6^{th} hr		0.04	0.00
		T-19 - 0-17"		24^{th} hr		0.04	0.02
		T-20 - 17-30"		SETTLING VOLUME	(ml)	31	22
		T-21 - 30-60"		MOISTURE RETENTION	(percent)		
		T-22 - 60-84"		1/10 bar			
		T-23 - 84-120"		1/3 bar		28.6	25.9
				15 bar		13.3	12.2
				SOIL REACTION-pH			
				Paste		8.4	8.3
				1:5 H_2O		9.6	9.4
				1.2 0.01 M $CaCl_2$			
				ORGANIC CARBON	(percent)		
				AVAILABLE PHOSPHORUS	(ppm)		
				$CaCO_3$ EQUIVALENT	(percent)		
				GYPSUM REQUIREMENT	(me/100g)		
				SATURATION EXTRACT			
				Saturation Percentage		46.1	45.3
				EC_e @ 25°C	(mmhos/cm)	2.00	3.60
				Ca^{++}	(me/l)	0.70	1.70
				Mg^{++}	(me/l)	4.20	10.20
				Na^{+}	(me/l)	14.50	24.10
				K^{+}	(me/l)	0.20	0.50
				CO_3^{-}	(me/l)	0.00	0.00
				HCO_3^{-}	(me/l)	3.80	2.70
				Cl^{-}	(me/l)	0.00	0.10
				SO_4^{-}	(me/l)	15.00	33.50
				NO_3^{-}	(me/l)	0.20	0.20
				SAR	(me/l)	9.30	9.90
				Na	(me/100g)	0.70	1.10
				Ca+Mg	(me/100g)	0.20	0.50
				1:5 EXTRACT			
				EC_5 @ 25°C	(mmhos/cm)	0.36	0.55
				Ca+Mg	(me/l)	1.50	1.60
				EXCHANGEABLE SODIUM	(percent)	12.90	11.20
				ACIDITY			
				1N KCl exchange acidity			
				Total	(me/100g)		
				Al^{+++}	(me/100g)		
				CATION EXCHANGE CAPACITY	(me/100g)	13.9	18.7
				NaOAc@pH 8.2			
				BORON	(mg/l)		

Table 26
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Lacation. Sec. 24 Twp. 2 S. Range 44 E
Climate: Continental, semi-arid
Land Use: Rangeland
Paint Site Number: 9

Relief: Single, plane
Elevatian: 3140 Ft
Slope: Aspect: 1-2%, W
Vegetation: Western wheatgrass; Silver sagebrush
Erasion: Slight

Staniness:
Drainage: Well drained
Ground Water:
Land Farm: Bottomland - Double E Coulee

Parent Material: Alluvium/Colluvium
Soil Series: Farnuf*
Sail Classificatian Fine-loamy, mixed, Typic Argiboroll

Profile Descriptian By: W. Volk Date 1/83
Correlated By: W. Volk Date 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION		
V - 39 21,139	0.0-4.0	A1	Dark grayish brown (10YR 4/2) loam; dark brown (10YR 3/3) moist; single grain structure; very friable; nonsticky; nonplastic; noneffervescent.	
V - 40 21,140	4.0-8.0	B2t	Brown (10YR 4/3) silt loam; very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; slightly hard; friable; slightly sticky; slightly plastic; slight effervescence.	
V - 41 21,141	8.0-14.0	B3k	Pale brown (10YR 6/3) clay loam; brownish yellow (10YR 6/6) moist; moderate medium prismatic structure breaks to weak medium angular blocky; hard; firm; sticky; slightly plastic; violent effervescence.	
V - 42 21,142	14.0-27.0	C1k	Light yellowish brown (10YR 6/4) silt loam; yellowish brown (10YR 5/4) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence.	
V - 43 21,143	27.0-48.0	C2	Light yellowish brown (10YR 6/4) silty clay loam; yellowish brown (10YR 5/6) moist; massive; firm; slightly sticky; slightly plastic; slight effervescence.	
V - 44 21,144	48.0-76.0	IIC3	Very pale brown (10YR 7/3) silty clay loam; yellowish brown (10YR 5/6) moist; massive; firm; slightly sticky; slightly plastic; strong effervescence.	

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		21,139	21,140	21,141	21,142	21,143	21,144
DEPTH	(in)	0.0-4.0	4.0-8.0	8.0-14.0	14.0-27.0	27.0-48.0	48.0-76.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)	2.8					
Coarse Sand	(1.0-0.5mm)	1.5					
Medium Sand	(0.5-0.25mm)	1.6					
Fine Sand	(0.25-0.10mm)	25.1					
Very Fine Sand	(0.10-0.05mm)	16.8					
Total Sand	(2.0-0.05mm)	47.8	39.3	21.8	15.2	42.4	25.7
Silt	(0.05-0.002mm)	38.4	39.6	48.6	57.5	38.9	50.2
Clay	(<0.002mm)	13.8	21.1	29.6	27.3	18.7	24.1
TEXTURAL CLASS (LAB)		L	L	CL	SiCL	L	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.63	0.13	0.16	0.06	0.02	0.00
24th hr		0.69	0.13	0.16	0.06	0.02	0.00
SETTLING VOLUME	(ml)	17	23	24	24	19	28
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		8.4	15.2	18.7	11.0	6.7	10.7
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.4	8.1	9.0	9.0	9.4	9.4
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)	1.63	2.38				
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+2.74	+2.45	+2.23	+2.89	+3.39	+2.75
SATURATION EXTRACT							
Saturation Percentage		44.9	41.3	42.3	48.1	37.9	47.9
EC_e @ 25°C	(mmhos/cm)	0.87	1.24	0.81	5.00	6.60	10.70
Ca^{++}	(me/l)	5.65	8.51	3.57	11.20	4.56	7.52
Mg^{++}	(me/l)	2.80	4.16	3.17	25.87	26.87	48.76
Na^{+}	(me/l)	0.24	0.76	1.48	29.99	52.61	95.22
K^{+}	(me/l)	1.40	1.31	1.04	2.01	2.26	3.65
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	7.76	6.02	4.90	2.41	1.94	1.31
Cl^{-}	(me/l)	0.20	1.30	0.32	1.48	1.60	3.09
SO_4^{-}	(me/l)	0.51	6.29	3.33	64.54	83.28	145.74
NO_3^{-}	(me/l)	1.25	0.001	0.00	0.09	0.15	0.18
SAR	(me/l)	0.11	0.30	0.81	7.00	13.00	18.00
Na	(me/100g)	0.01	0.03	0.06	1.44	1.99	4.56
Ca+Mg	(me/100g)	0.38	0.52	0.28	1.78	1.19	2.70
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.14	0.26	0.17	0.86	0.80	1.15
Ca+Mg	(me/l)	0.97	1.91	1.17	4.26	1.85	4.08
EXCHANGEABLE SODIUM	(percent)	0.33	1.07	1.18	6.79	17.93	16.75
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	15.00	16.09	13.91	14.67	8.15	16.74
NaOAc@pH 8.2							
BORON	(mg/l)						

* Taxadjunct to series because of higher sodium and salt content in the substratum than is defined as the range for this series.

Table 27
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Locotion. Sec. 24 Twp. 2 S. Ronge 44 E
Climate. Continental, semi-arid
Lond Use: Rangeland
Point Site Number: 9 (con't)

Relief: Single, plane
Elevotion: 3140 Ft
Slope: Aspect: 1-2%; W
Vegetation: Western wheatgrass; Silver sagebrush
Erosion: Slight

Stoniness:
Droinage: Well drained
Ground Water:
Land Form: Bottomland - Double E Coulee

Porent Material: Alluvium/Colluvium
Soil Series: Farnuf *
Soil Classification: Fine-loamy, mixed, Typic Argiboroll
Profile Description By: W. Volk Dote 1/83
Correlated By: W. Volk Date 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION		LABORATORY DESCRIPTION		
				DETERMINATION		DATA
V - 45 21,145	76.0-94.0	IIC4	Light yellowish brown (10YR 6/4) silty clay loam; yellowish brown (10YR 5/4) moist; massive; firm slightly sticky; slightly plastic; strong effervescence.	LABORATORY NUMBER		21,145 3932
				DEPTH	(in)	76.0-94.0 94.0-120.0
				PARTICLE SIZE ANALYSIS	(percent)	
				Very Coarse Sand	(2.0-1.0mm)	2.0
				Coarse Sand	(1.0-0.5mm)	1.8
				Medium Sand	(0.5-0.25mm)	1.9
				Fine Sand	(0.25-0.10mm)	25.9
				Very Fine Sand	(0.10-0.05mm)	14.0
				Total Sand	(2.0-0.05mm)	45.6 38.4
				Silt	(0.05-0.002mm)	35.1 50.8
				Clay	(<0.002mm)	19.3 10.8
				TEXTURAL CLASS (LAB.)		L SiL
				BULK DENSITY	(g/cm^3)	
				HYDRAULIC CONDUCTIVITY	(in/hr)	
				6^{th} hr		0.00 0.55
				24^{th} hr		0.00 0.43
				SETTLING VOLUME	(ml)	27 18
				MOISTURE RETENTION	(percent)	
				1/10 bar		
				1/3 bar		13.1
				15 bar		8.5 6.1
				SOIL REACTION-pH		
				Paste		8.4
				1:5 H_2O		9.6 8.3
				1:2 0.01 M $CaCl_2$		
				ORGANIC CARBON	(percent)	
				AVAILABLE PHOSPHORUS	(ppm)	
				$CaCO_3$ EQUIVALENT	(percent)	
				GYPSUM REQUIREMENT	(me/100g)	
				SATURATION EXTRACT		
				Saturation Percentage		39.3 26.5
				EC_e @ 25°C	(mmhos/cm)	8.05 5.60
				Ca^{++}	(me/l)	4.12 0.40
				Mg^{++}	(me/l)	23.88 13.80
				Na^{+}	(me/l)	74.70 44.40
				K^{+}	(me/l)	2.69 1.40
				CO_3^{-}	(me/l)	0.00 0.00
				HCO_3^{-}	(me/l)	1.59 2.80
				Cl^{-}	(me/l)	4.11 1.60
				SO_4^{-}	(me/l)	99.94 58.00
				NO_3^{-}	(me/l)	0.20 0.10
				SAR	(me/l)	20.00 16.60
				Na	(me/100g)	2.94 1.20
				Ca+Mg	(me/100g)	1.10 0.40
				1:5 EXTRACT		
				EC_5 @ 25°C	(mmhos/cm)	1.03 0.55
				Ca+Mg	(me/l)	1.42 0.70
				EXCHANGEABLE SODIUM	(percent)	25.24 20.30
				ACIDITY		
				1N KCl exchange acidity		
				Total	(me/100g)	
				Al^{+++}	(me/100g)	
				CATION EXCHANGE CAPACITY	(me/100g)	9.02 6.90
				NaOAc @ pH 8.2		
				BORON	(mg/l)	
		Greenhouse Samples				
		T-32 - 0-8"				
		T-33 - 8-27"				
		T-34 - 27-48"				
		T-35 - 48-76"				
		T-36 - 76-94"				
		T-37 - 94-120"				
T - 37 3932	94.0-120.0	IIIC5	Not logged			

* Taxadjunct to series because of higher sodium and salt content in the substratum than is defined as the range for this series.

Table 27
Sheet 2 of 2

7-2006A (1-78)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location, Sec. 32 Twp. 2 S. Range 45 E.
1250' S and 1050' E of N¼
Climate: Continental - semi-arid
Land Use: Rangeland
Point Site Number: 12

Relief: Convex; Single
Elevation: 3280 Ft
Slope: Aspect: 2%, SW
Vegetation: Western Wheatgrass, Big sagebrush
Erosion: Slight

Stoniness:
Drainage: Well drained
Ground Water:
Land Form: Low terrace

Parent Material: Local alluvium - clayey
Soil Series: Gerdrum
Soil Classification: Fine, montmorillonitic, Borollic Natrargid
Profile Description By: W. Volk Date 1/83
Correlated By: W. Volk Date 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
V-6 21,106	0 - 0.5	A11	Brown (10YR 4/3) silty clay loam; dark brown (10YR 3/3) moist; strong very fine granular structure; loose; very friable; sticky; plastic; noneffervescent; clear smooth boundary.
V-7 21,107	0.5 - 2.0	A12	Brown (10YR 5/3) silty clay loam; brown (10YR 4/3) moist; moderate fine platy structure; slightly hard; friable; sticky; plastic; slightly effervescent; clear smooth boundary.
V-8 21,108	2.0 - 5.0	B1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate medium angular blocky structure; hard; friable; sticky; plastic; slightly effervescent; clear smooth boundary.
V-9 21,109	5.0 - 8.0	B21	Brown (10YR 5/3) heavy silty clay loam; brown (10YR 4/3) moist; moderate medium prismatic structure breaks to strong medium angular blocky; hard; friable; sticky; plastic; slightly effervescent; clear wavy boundary.
V-10 21,110	8.0 - 17.0	B22t	Brown (10YR 5/3) silty clay; brown (10YR 4/3) moist; strong coarse prismatic structure separates to strong medium angular blocky; very hard; friable; sticky; plastic, slightly effervescent; clear wavy boundary.
V-11 21,111	17.0 - 22.0	B3	Yellowish brown (10YR 5/4) silty clay loam; dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parts to strong medium angular blocky; very hard; friable, sticky; plastic; slightly effervescent; clear irregular boundary.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		21,106	21,107	21,108	21,109	21,110	21,111
DEPTH	(in)	0.0 - 0.5	0.5 - 2.0	2.0 - 5.0	5.0 - 8.0	8.0 - 17.0	17.0 - 22.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)				0.8		
Coarse Sand	(1.0-0.5mm)				0.3		
Medium Sand	(0.5-0.25mm)				0.8		
Fine Sand	(0.25-0.10mm)				11.6		
Very Fine Sand	(0.10-0.05mm)				11.1		
Total Sand	(2.0-0.05mm)	42.0	33.0	27.2	24.6	20.9	22.9
Silt	(0.05-0.002mm)	39.1	35.0	36.8	38.5	38.7	41.0
Clay	(<0.002mm)	18.9	32.0	36.0	36.9	40.4	36.1
TEXTURAL CLASS (LAB)		L	CL	CL	CL	C	CL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.16	0.28	0.20	0.08	0.00	0.00
24th hr		0.10	0.20	0.20	0.10	0.00	0.02
SETTLING VOLUME	(ml)	21	24	23	24	31	25
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		10.1	14.3	14.0	13.6	16.2	15.0
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.5	8.2	8.6	8.9	9.5	9.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.99	-1.50	-1.30	-0.65	+2.1	-0.64
SATURATION EXTRACT							
Saturation Percentage		42.4	48.8	46.2	46.4	57.7	58.6
EC_e @ 25°C	(mmhos/cm)	0.79	0.94	0.65	0.85	1.60	10.00
Ca^{++}	(me/l)	4.45	5.43	3.18	1.70	0.82	21.30
Mg^{++}	(me/l)	3.53	3.80	2.26	1.72	1.80	45.77
Na^{+}	(me/l)	0.72	1.24	2.20	6.46	15.11	85.75
K^{+}	(me/l)	0.96	0.57	0.25	0.13	0.12	0.55
CO_3^{-}	(me/l)	0.27	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	8.06	6.79	5.70	5.90	7.70	2.25
Cl^{-}	(me/l)	0.21	0.56	0.60	0.39	1.02	1.74
SO_4^{-}	(me/l)	0.86	1.50	1.12	2.79	9.99	147.82
NO_3^{-}	(me/l)	0.004	1.82	0.015	0.008	0.006	0.04
SAR	(me/l)	0.36	0.58	1.30	4.90	13.00	15.00
Na	(me/100g)	0.03	0.06	0.10	0.30	0.87	5.03
Ca+Mg	(me/100g)	0.34	0.45	0.25	0.16	0.15	3.93
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.11	0.19	0.15	0.17	0.33	2.10
Ca+Mg	(me/l)	1.01	1.53	1.16	1.00	1.69	9.44
EXCHANGEABLE SODIUM	(percent)	0.44	0.66	1.70	3.84	14.99	27.10
ACIDITY							
1N KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	17.72	25.33	25.65	24.24	23.70	21.74
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 28
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Locotion. Sec. 32 Twp. 2 S. Ronge 45 E.
1250' S and 1050' E of N¼
Climate: Continental - Semi-arid
Lond Use: Rangeland
Point Site Number: 12 (cont'd)

Relief: Convex ; single
Elevotion: 3280 Ft
Slope: Aspect: 2%, SW
Vegetotion: Western Wheatgrass, Big sagebrush
Erosion: Slight

Stoniness:
Droinoge: Well drained
Ground Woter:
Lond Form: Low Terrace

Porent Moteriol: Local alluvium - clayey
Soil Series: Gerdrum
Soil Clossificotion: Fine, montmorillonitic, Borollic Natrargid
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
V-12 21,112	22.0 - 36.0	C1k	Light yellowish brown (10YR 6/4) silty clay loam; brown (10YR 5/3) moist; massive; very hard; firm; sticky; plastic; strongly effervescent; gradual wavy boundary.
V-13 21,113	36.0 - 60.0	C2k	Light yellowish brown (10YR 6/4) silty clay loam; yellowish brown (10YR 5/4) moist; massive; hard; firm; sticky; plastic; strongly effervescent.
T-10 3905	60.0 - 84.0	C3	Light yellowish brown (10YR 6/4) silty clay loam; yellowish brown (10YR 5/4) moist; massive; hard; firm; sticky; plastic; strongly effervescent.
T-11 3906	84.0 - 102.0	C4	Yellowish brown (10YR 5/4) clay loam; brown (10YR 5/3) moist; massive; slightly firm; sticky; plastic; strongly effervescent.
T-12 3907	102.0 - 120.0	C5	Oark yellowish brown (10YR 4/4) clay; brown (10YR 4/3); massive; hard; very firm; very sticky; very plastic; strongly effervescent.

Greenhouse Samples

T-6 - 0-8"
T-7 - 8-17"
T-8 - 17-36"
T-9 - 36-60"
T-10 - 60-84"
T-11 - 84-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		21,112	21,113	3905	3906	3907
DEPTH	(in)	22.0-36.0	36.0-60.0	60.0-84.0	84.0-102.0	102.0-120.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0mm)					
Coarse Sand	(1.0-0.5mm)					
Medium Sand	(0.5-0.25mm)					
Fine Sand	(0.25-0.10mm)					
Very Fine Sand	(0.10-0.05mm)					
Total Sand	(2.0-0.05mm)	21.9	33.6	26.5	25.7	29.0
Silt	(0.05-0.002mm)	43.9	39.6	50.9	47.0	47.0
Clay	(<0.002mm)	34.8	26.8	22.6	27.3	24.0
TEXTURAL CLASS (LAB.)		CL	L	SiL	CL	L
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6^{th} hr		0.02	0.06	0.16	0.10	0.14
24^{th} hr		0.02	0.06	0.12	0.12	0.08
SETTLING VOLUME	(ml)	25	25	36	34	42
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar				21.3	22.7	21.3
15 bar		15.1	10.6	10.3	11.9	11.0
SOIL REACTION-pH						
Paste				8.1	7.8	7.8
1:5 H_2O		8.8	8.7	9.0	8.6	8.6
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-2.0	-5.3			
SATURATION EXTRACT						
Saturation Percentage		55.7	47.0	45.9	52.7	49.1
EC_e @ 25°C	(mmhos/cm)	11.30	10.40	9.50	8.00	8.00
Ca^{++}	(me/l)	21.30	27.45	20.20	6.20	20.60
Mg^{++}	(me/l)	52.74	40.80	32.40	19.60	28.20
Na^{+}	(me/l)	102.59	91.01	70.00	61.90	58.80
K^{+}	(me/l)	0.90	1.29	0.90	0.80	0.80
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	2.10	2.16	1.30	1.30	1.50
Cl^{-}	(me/l)	1.69	0.96	1.00	6.50	0.10
SO_4^{-}	(me/l)	168.02	156.15	122.00	90.00	106.00
NO_3^{-}	(me/l)	0.25	0.27	0.20	0.20	0.10
SAR	(me/l)	17.00	16.00	13.60	17.20	11.90
Na	(me/100g)	5.71	4.28	3.20	32.60	2.90
Ca+Mg	(me/100g)	4.12	3.21	2.40	1.40	2.40
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	2.70	2.30	1.70	3.00	1.70
Ca+Mg	(me/l)	16.74	14.86	7.90	26.40	8.60
EXCHANGEABLE SODIUM	(percent)	27.89	19.39	15.30		7.60
ACIDITY						
1N KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	21.96	17.28	13.10	18.8	26.3
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 28
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Locotion. Sec. 29 Twp. 2 S. Ronge 45 E.
125' N and 125' E of SW corner
Climote: Continental, semi-arid
Lond Use: Rangeland
Point Site Number: 6

Relief: Single, plane
Elevotion: 3330 Ft
Slope: Aspect: 2%, SE
Vegetotion: Western wheatgrass, Blue grama
Erosion: Slight

Stoniness:
Droinoge: Well drained
Ground Woter:
Lond Form: Upland terrace

Parent Moteriol: Local alluvium
Soil Series: Farnuf
Soil Clossification: Fine-loamy mixed
Typic Argiboroll
Profile Description By: W. Volk Date 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION		LABORATORY DESCRIPTION						
				DETERMINATION		DATA				
				LABORATORY NUMBER		21,114	21,115	21,116	21,117	21,118	21,119
V - 14 21,114	0.0 - 2.5	A1	Yellowish brown (10YR 5/4) silt loam; dark brown (10YR 3/3) moist; weak medium platy structure to moderate fine granular; loose; very friable; slightly sticky; slightly plastic, noneffervescent; abrupt smooth boundary.	DEPTH	(in)	0.0-2.5	2.5-6.0	6.0-17.0	17.0-23.0	23.0-32.0	32.0-54.0
V - 15 21,115	2.5 - 6.0	B21	Brown (10YR 4/3) silt loam; very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure breaks to moderate medium subangular blocky; slightly hard; very friable; slightly sticky; slightly plastic; noneffervescent; clear wavy boundary.	PARTICLE SIZE ANALYSIS	(percent)						
				Very Coarse Sand	(2.0-1.0mm)						
				Coarse Sand	(1.0-0.5mm)						
				Medium Sand	(0.5-0.25mm)						
				Fine Sand	(0.25-0.10mm)						
				Very Fine Sand	(0.10-0.05mm)						
				Total Sand	(2.0-0.05mm)	33.3	30.4	27.9	27.5	28.6	32.8
				Silt	(0.05-0.002mm)	55.1	45.6	44.2	46.3	47.0	46.8
				Clay	(<0.002mm)	11.6	24.0	27.9	26.2	24.4	20.4
				TEXTURAL CLASS (LAB)		SiL	L	CL	L	L	L
V - 16 21,116	6.0 - 17.0	B22t	Dark yellowish brown (10YR 4/4) silty clay loam; brown (10YR 4/3) moist; moderate coarse prismatic structure separates to moderate medium angular blocky; hard; firm; sticky; plastic; noneffervescent; clear smooth boundary.	BULK DENSITY	(g/cm^3)						
				HYDRAULIC CONDUCTIVITY	(in/hr)						
				6th hr		0.26	0.16	0.06	0.12	0.14	0.31
				24th hr		0.24	0.16	0.06	0.14	0.12	0.31
				SETTLING VOLUME	(ml)	20	22	23	21	20	19
				MOISTURE RETENTION	(percent)						
				1/10 bar							
				1/3 bar							
				15 bar							
V - 17 21,117	17.0 - 23.0	B3k	Pale brown (10YR 6/3) silt loam; brown (10YR 5/3) moist; moderate coarse prismatic structure parts to strong medium angular blocky; hard; friable; slightly sticky; slightly plastic; strongly effervescent; abrupt wavy boundary.	SOIL REACTION-pH		6.8	9.7	11.2	9.0	8.1	7.0
				Paste							
				1:5 H_2O		6.8	6.7	7.6	8.9	9.0	9.4
				1:2 0.01 M $CaCl_2$							
				ORGANIC CARBON	(percent)	1.68	1.43	1.12			
				AVAILABLE PHOSPHORUS	(ppm)						
				$CaCO_3$ EQUIVALENT	(percent)						
				GYPSUM REQUIREMENT	(me/100g)	-1.3	+0.12	-0.19	-1.7	+0.32	+0.12
V - 18 21,118	23.0 - 32.0	C1k	Pale brown (10YR 6/3) clay loam; brown (10YR 5/3) moist; weak medium prismatic structure breaks to moderate medium angular blocky; hard; friable; slightly sticky, slightly plastic; violently effervescent; clear wavy boundary.	SATURATION EXTRACT							
				Saturation Percentage		38.5	38.9	45.0	43.0	39.7	37.5
				EC_e @ 25°C	(mmhos/cm)	0.65	0.48	0.83	0.43	0.40	0.53
				Ca^{++}	(me/l)	4.23	3.51	5.71	2.09	1.37	0.71
				Mg^{++}	(me/l)	2.62	2.17	3.89	2.35	2.35	2.17
				Na^{+}	(me/l)	0.81	0.38	0.81	0.53	0.81	2.97
				K^{+}	(me/l)	1.00	0.30	0.19	0.13	0.14	0.15
				CO_3^{-}	(me/l)	0.00	0.00	0.15	0.00	0.00	0.00
				HCO_3^{-}	(me/l)	5.43	4.47	7.59	3.72	3.44	4.19
				Cl^{-}	(me/l)	0.14	0.15	0.27	0.10	0.10	0.31
				SO_4^{-}	(me/l)	2.50	0.78	1.63	0.44	0.52	1.15
				NO_3^{-}	(me/l)	0.006	0.00	0.00	0.19	0.21	0.12
				SAR	(me/l)	0.44	0.23	0.37	0.35	0.60	2.50
				Na	(me/100g)	0.03	0.01	0.04	0.02	0.03	0.11
				Ca+Mg	(me/100g)	0.26	0.22	0.43	0.19	0.15	0.11
				1:5 EXTRACT							
				EC_5 @ 25°C	(mmhos/cm)	0.093	0.05	0.19	0.12	0.12	0.15
				Ca+Mg	(me/l)	0.46	0.58	1.71	1.19	1.07	0.88
				EXCHANGEABLE SODIUM	(percent)	0.79	0.50	0.57	0.83	1.04	4.84
				ACIDITY							
				1N KCl exchange acidity							
				Total	(me/100g)						
				Al^{+++}	(me/100g)						
				CATION EXCHANGE CAPACITY	(me/100g)	12.72	18.37	22.83	14.57	13.04	12.28
				NaOAc@pH 8.2							
V - 19 21,119	32.0 - 54.0	C2	Pale brown (10YR 6/3) very fine sandy loam; brown (10YR 5/3) moist; massive; hard; friable; slightly sticky; slightly plastic; slightly effervescent; diffuse wavy boundary.	BORON	(mg/l)						

Table 29
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 29 Twp. 2 S. Ronge 45 E.
125' N and 125' E of SW corner
Climate: Continental, semi-arid
Land Use: Rangeland
Point Site Number: 6 (con't)

Relief: Single, plane
Elevation: 3330 Ft
Slope: Aspect: 2%, SE
Vegetation: Western wheatgrass, Blue grama
Erosion: Slight

Stoniness:
Drainage: Well drained
Ground Water:
Land Form: Upland terrace

Parent Material: Local alluvium
Soil Series: Farnuf
Soil Classification: Fine-loamy, mixed
Typic Argiboroll
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
V - 20 21,120 V - 21 21,121	54.0 - 78.0 78.0 - 102.0	C3 Pale brown (10YR 6/3) loam; brown (10YR 5/3) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; slightly effervescent.
V - 22 21,122	102.0 - 120.0	C4 Very pale brown (10YR 7/4) sandy clay loam; yellowish brown (10YR 5/6) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; slightly effervescent.
		Greenhouse Samples T-13 - 0-17" T-14 - 17-32" T-15 - 32-54" T-16 - 54-78" T-17 - 78-102" T-18 - 102-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA		
LABORATORY NUMBER		21,120	21,121	21,122
DEPTH	(in)	54.0-78.0	78.0-102.0	102.0-120.0
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0 mm)		0.3	0.7
Coarse Sand	(1.0-0.5 mm)		0.4	1.0
Medium Sand	(0.5-0.25 mm)		0.6	2.8
Fine Sand	(0.25-0.10 mm)		13.5	26.4
Very Fine Sand	(0.10-0.05 mm)		29.9	21.3
Total Sand	(2.0-0.05 mm)	35.4	44.7	52.2
Silt	(0.05-0.002 mm)	46.5	38.0	31.7
Clay	(<0.002 mm)	18.1	17.3	16.1
TEXTURAL CLASS (LAB)		L	L	VFSL
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th hr		0.37	0.24	0.18
24th hr		0.41	0.26	0.18
SETTLING VOLUME	(ml)	19	19	18
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar		6.6	6.2	6.1
SOIL REACTION-pH				
Paste				
1:5 H_2O		9.4	9.7	9.7
1:2 0.01 M $CaCl_2$				
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
$CaCO_3$ EQUIVALENT	(percent)			
GYPSUM REQUIREMENT	(me/100g)	+0.56	-0.13	+1.28
SATURATION EXTRACT				
Saturation Percentage		36.4	36.1	32.4
EC_e @ 25°C	(mmhos/cm)	1.03	2.05	1.75
Ca^{++}	(me/l)	0.49	0.55	0.44
Mg^{++}	(me/l)	2.44	4.79	2.71
Na^{+}	(me/l)	8.51	17.70	15.21
K^{+}	(me/l)	0.18	0.30	0.23
CO_3^{-}	(me/l)	0.00	0.00	0.00
HCO_3^{-}	(me/l)	5.27	5.28	5.21
Cl^{-}	(me/l)	1.14	1.62	1.16
SO_4^{-}	(me/l)	4.16	15.09	11.45
NO_3^{-}	(me/l)	0.07	0.07	0.09
SAR	(me/l)	7.00	11.00	12.00
No	(me/100g)	0.31	0.64	0.49
Ca+Mg	(me/100g)	0.11	0.19	0.10
1:5 EXTRACT				
EC_5 @ 25°C	(mmhos/cm)	0.22	0.33	0.30
Ca+Mg	(me/l)	0.73	0.60	0.58
EXCHANGEABLE SODIUM	(percent)	8.74	13.03	15.59
ACIDITY				
IN KCl exchonge acidity				
Total	(me/100g)			
Al^{+++}	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	11.63	11.52	10.11
NaOAc @ pH 8.2				
BORON	(mg/l)			

Table 29
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 30 Twp. 2 S. Range 45 E.
1250' W. and 1000' S. of E¼
Climate: Continental - Semi - arid
Land Use: Cropland
Point Site Number: 9

Relief: Single, concave
Elevation: 3310 - feet
Slope: Aspect: 5%, S - SW
Vegetation: Crested wheatgrass, Smooth brome
Erosion: Slight

Stoniness:
Drainage: Well - drained
Ground Water:
Land Form: Alluvial footslope

Parent Material: Local alluvium - sandy
Soil Series: Farnuf
Soil Classification: Fine - loamy, mixed
Typic Argiboroll
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
V-1 21,101	0 - 7	Ap	Dark brown (10YR 4/3) silt loam; very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure; loose; very friable; slightly sticky; slightly plastic; noneffervescent; clear smooth boundary.
V-2 21,102	7 - 10	B21t	Brown (10YR 5/3) silty clay loam; dark brown (10YR 3/3) moist; moderate coarse prismatic structure separates to moderate medium angular blocky; slightly hard; friable; slightly sticky; slightly plastic; non-effervescent; clear smooth boundary.
V-3 21,103	10 - 13	B22	Brown (10YR 5/3) loam; dark brown (10YR 3/3) moist; strong coarse prismatic structure breaks to moderate medium angular blocky; slightly hard; friable; slightly sticky; slightly plastic; noneffervescent; clear smooth boundary.
V-4 21,104	13 - 18	B3k	Yellowish brown (10YR 5/4) loam; brown (10YR 5/3) moist; strong coarse prismatic structure separates to strong medium angular blocky; hard; friable; slightly sticky; slightly plastic; strong effervescence; clear wavy boundary.
V-5 21,105	18 - 39	C1k	Light yellowish brown (10YR 6/4) loam; brown (10YR 5/3) moist; massive; hard; friable; slightly sticky, slightly plastic; strong effervescence; diffuse wavy boundary.
T-3 3898	39 - 60	C2	Pale brown (10YR 6/3) loam; brown (10YR 5/3) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; slightly effervescent; gradual wavy boundary.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		21,101	21,102	21,103	21,104	21,105	3898
DEPTH	(in)	0 - 7	7 - 10	10 - 13	13 - 18	18 - 39	39 - 60
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0mm)	1.2					
Coarse Sand	(1.0-0.5mm)	0.3					
Medium Sand	(0.5-0.25mm)	0.9					
Fine Sand	(0.25-0.10mm)	18.8					
Very Fine Sand	(0.10-0.05mm)	23.1					
Total Sand	(2.0-0.05mm)	44.3	40.7	40.8	39.6	40.0	44.3
Silt	(0.05-0.002mm)	35.6	33.5	34.6	33.6	33.5	50.7
Clay	(<0.002mm)	20.1	25.8	24.6	26.8	26.5	5.0
TEXTURAL CLASS (LAB)		L	L	L	L	L	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.55	0.39	0.24	0.18	0.12	0.63
24th hr		0.55	0.51	0.30	0.22	0.12	0.47
SETTLING VOLUME	(ml)	21	23	23	23	21	19
MOISTURE RETENTION	(percent)						
1/10 bar							13.9
1/3 bar							
15 bar		9.2	11.1	10.4	10.2	9.9	6.9
SOIL REACTION-pH							
Paste							8.2
1:5 H_2O		7.1	7.2	8.4	8.7	8.9	9.0
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)	1.29					
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-1.0	-1.2	-1.2	-1.7	-1.1	
SATURATION EXTRACT							
Saturation Percentage		35.2	41.2	44.9	40.9	41.6	35.0
EC_e @ 25°C	(mmhos/cm)	0.53	0.67	0.67	0.48	0.38	0.36
Ca^{++}	(me/l)	3.18	4.01	4.89	3.18	2.09	0.40
Mg^{++}	(me/l)	1.99	2.53	2.26	1.72	1.90	2.50
Na^{+}	(me/l)	0.77	1.48	1.10	0.38	0.33	0.60
K^{+}	(me/l)	0.38	0.19	0.14	0.13	0.14	0.10
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	3.90	5.09	6.00	4.23	3.70	3.00
Cl^{-}	(me/l)	0.15	0.17	0.17	0.16	0.12	0.00
SO_4^{-}	(me/l)	1.77	2.31	1.71	0.46	0.44	0.30
NO_3^{-}	(me/l)	0.003	0.003	0.001	0.16	0.025	0.70
SAR	(me/l)	0.48	0.82	0.58	0.24	0.24	0.50
Na	(me/100g)	0.03	0.06	0.05	0.02	0.01	0.00
Ca+Mg	(me/100g)	0.18	0.27	0.32	0.20	0.17	0.10
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.059	0.053	0.15	0.12	0.12	0.12
Ca+Mg	(me/l)	0.74	0.83	1.51	1.29	1.80	1.40
EXCHANGEABLE SODIUM	(percent)	0.19	0.16	0.22	0.47	0.52	0.80
ACIDITY							
1N KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	16.85	21.52	21.30	17.07	15.76	14.90
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 30
Sheet 1 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Cook Mountain, Montana
Location. Sec. 30 Twp. 2 S. Range 45 E.
1250' W. and 1000' S. of E¼
Climate: Continental - Semi-arid
Land Use: Cropland
Point Site Number: 9 (cont'd)

Relief: Single, concave
Elevation: 3310 - feet
Slope: Aspect: 5%, S - SW
Vegetation: Crested wheatgrass, Smooth brome
Erosion: Slight

Stoniness:
Drainage: Well - drained
Ground Water:
Land Form: Alluvial footslope

Parent Material: Local alluvium - sandy
Soil Series: Farnuf
Soil Classification: Fine - loamy, mixed
Typic Argiboroll
Profile Description By: W. Volk Date: 1/83
Correlated By: W. Volk Date: 1/83

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T-4 3899	60 - 96	C3 Pale brown (10YR 6/3) very fine sandy loam; brown (10YR 5/3) moist; loose; soft, very friable; slightly sticky; slightly plastic; noneffervescent; gradual wavy boundary.
T-5 3900	96 - 120+	C4 Pale brown (10YR 6/3) sandy clay loam; brown (10YR 5/3) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; noneffervescent.

Greenhouse Samples

T-1 - 0-13"
T-2 - 13-39"
T-3 - 39-60"
T-4 - 60-96"
T-5 - 96-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		3899	3900
DEPTH	(in)	60 - 96	96 - 120
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0mm)		0.1
Coarse Sand	(1.0-0.5mm)		0.3
Medium Sand	(0.5-0.25mm)		0.8
Fine Sand	(0.25-0.10mm)		18.6
Very Fine Sand	(0.10-0.05mm)		30.8
Total Sand	(2.0-0.05mm)	36.0	50.6
Silt	(0.05-0.002mm)	60.1	33.9
Clay	(<0.002mm)	3.9	15.5
TEXTURAL CLASS (LAB.)		SiL	L
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		1.06	0.28
24th hr		0.43	0.20
SETTLING VOLUME	(ml)	16	17
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar		12.4	12.2
15 bar		6.0	6.1
SOIL REACTION-pH			
Paste		8.4	8.4
1:5 H_2O		9.3	9.4
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage		34.3	33.2
EC_e @ 25°C	(mmhos/cm)	0.44	0.58
Ca^{++}	(me/l)	0.20	0.30
Mg^{++}	(me/l)	2.30	1.90
Na^{+}	(me/l)	1.70	3.30
K^{+}	(me/l)	0.20	0.20
CO_3^{-}	(me/l)	0.00	0.00
HCO_3^{-}	(me/l)	3.50	3.70
Cl^{-}	(me/l)	0.00	0.00
SO_4^{-}	(me/l)	0.50	1.40
NO_3^{-}	(me/l)	0.10	0.10
SAR	(me/l)	1.50	3.10
Na	(me/100g)	0.00	0.00
Ca+Mg	(me/100g)	0.10	0.10
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.20	0.11
Ca+Mg	(me/l)	1.22	0.60
EXCHANGEABLE SODIUM	(percent)	0.40	3.40
ACIDITY			
IN KCl exchange acidity			
Total	(me/100g)		
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	10.2	14.6
NaOAc@pH 8.2			
BORON	(mg/l)		

Table 30
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH OAKOTA

SOIL ANALYSIS OATA SHEET

INTRASEARCH, INC. ORILL HOLE 24530-2C

Study Area: Cook Mountain, Mt | Relief: | Stoniness: | Parent Material:

Location. Sec. 30 Twp. 2S Range 45E | Elevation: | | Soil Series:

| Slope Aspect: | Orainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Oate:

DETERMINATION		DATA (mg/1)					
Laboratory Number		27,403	27,404	27,405	27,406	27,407	27,408
Sack Number							
Oepth		I5.0-24.8	25.0-33.5	35.0-44.5	45.0-53.9	55.0-65.0	65.0-75.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.80	0.50	0.60	0.80	I.00	0.70
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.04	0.08	0.0I	0.02	0.03
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	I.45	1.89	3.10	0.70	1.47	1.84
IRON	Fe	28.40	109.00	I30.00	35.70	89.00	II6.00
MERCURY	Hg	0.032	0.057	0.074	0.030	0.065	0.078
LITHIUM	Li						
MANGANESE	Mn	7.69	14.40	20.50	9.26	12.60	17.30
MOLYBOENUM	Mo	0.20	0.28	0.4I	0.20	0.38	0.38
NICKEL	Ni	0.40	0.79	I.76	0.18	0.00	0.14
PHOSPHOROUS	P						
LEAD	Pb	3.50	5.00	9.40	1.80	2.80	9.70
STRONTIUM	Sr						
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02	0.02
VANADIUM	V						
ZINC	Zn	0.66	2.76	6.09	0.75	1.75	3.08

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		27,403	27,404	27,405	27,406	27,407	27,408
Sack Number							
OEPTH	(ft)	I5.0-24.8	25.0-33.5	35.0-44.5	45.0-53.9	55.0-65.0	54.0-75.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.I0 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	9.6	1I.1	7.5	9.3	7.8	9.3
SILT	(0.05-0.002 mm)	70.2	56.0	36.0	76.0	73.8	56.0
CLAY	(0.002 mm)	20.2	32.9	56.5	14.7	18.4	34.7
TEXTURAL CLASS (LAB)		SiL	SiCL	C	SiL	SiL	SiCL
BULK OENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.							
24th Hr.							
SETTLING VOLUME	(mI)						
MOISTURE RETENTION	(percent)						
I/10 bar							
I/3 bar							
15 bar							
SOIL REACTION-pH							
Paste		8.4	8.3	7.7	8.3	8.1	8.I
1:5 H_2O							
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)	0.I	0.I	0.1	0.I	0.I	0.1
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/I00g)						
SATURATION EXTRACT							
Saturation Percentage		34.0	38.9	52.0	34.6	36.2	44.0
EC_e @ 25 °C	(mmhos/cm)	I.73	1.80	2.35	1.31	I.6I	1.30
Ca^{++}	(me/1)	I.42	1.76	4.84	1.59	3.4I	3.12
Mg^{++}	(me/1)	4.45	3.93	8.I6	4.04	6.99	5.49
Na^{+}	(me/I)	13.60	14.30	14.30	9.06	8.54	6.20
K^{+}	(me/1)						
CO_3^{-}	(me/1)						
HCO_3^{-}	(me/1)						
Cl^{-}	(me/1)						
SO_4^{-}	(me/1)						
NO_3^{-}	(me/1)						
SAR	(me/1)	7.94	8.48	5.61	5.40	3.75	2.99
Na	(me/I00g)						
Ca+Mg	(me/I00g)						
1:5 EXTRACT							
$EC_{5:3}$ 25°C	(mmhos/cm)						
Ca+Mg	(me/1)						
EXCHANGEABLE SOOIUM	(percent)	7.08	6.86	5.49	5.02	4.27	3.95
ACIOITY							
IN KCL exchange acidity							
Total	(me/I00g)						
Al^{+++}	(me/I00g)						
CATION EXCHANGE CAPACITY	(me/I00g)	8.44	8.80	I0.50	6.I1	6.35	7.28
NaOAc@pH 8.2							
BORON	(mg/1)						

Table 34
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

INTRASEARCH, INC. DRILL HOLE 24530-2C (cont'd)

Study Area: Cook Mountain, Mt | Relief: | Stoniness: | Parent Material:

Location. Sec. 30 Twp. 2S. Range 45E. | Elevation: | | Soil Series:

| Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		27,409	27,410	27,411	27,412	27,413	27,414
Sack Number							
Depth		75.0-85.0	85.2-95.0	95.0-105.0	105.0-113.9	118.1-125.0	125.0-127.4
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.50	0.70	0.70	0.80	0.80	1.50
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.03	0.03	0.03	0.03	0.08	0.07
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.60	1.66	2.00	1.36	3.28	4.20
IRON	Fe	144.00	93.60	97.70	103.00	144.00	94.40
MERCURY	Hg	0.055	0.084	0.066	0.053	0.040	0.205
LITHIUM	Li						
MANGANESE	Mn	20.40	12.10	8.30	9.91	22.40	1.18
MOLYBDENUM	Mo	0.36	0.32	0.34	0.38	0.46	0.20
NICKEL	Ni	1.10	0.58	0.76	0.64	1.96	1.52
PHOSPHOROUS	P						
LEAD	Pb	6.00	4.30	4.20	4.00	14.80	14.70
STRONTIUM	Sr						
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02	0.02
VANADIUM	V						
ZINC	Zn	3.55	3.19	4.10	2.33	7.11	12.30

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		27,409	27,410	27,411	27,412	27,413	27,414
Sack Number							
DEPTH	(ft)	75.0-85.2	85.2-95.0	95.0-105.0	105.0-113.9	118.1-125.0	125.0-127.4
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	7.5	10.9	22.0	11.6	46.2	7.8
SILT	(0.05-0.002 mm)	48.9	74.4	66.9	75.7	24.7	26.7
CLAY	(0.002 mm)	43.6	14.7	11.1	12.7	29.1	65.5
TEXTURAL CLASS (LAB)		SiC	SiL	SiL	SiL	SCL	C
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.							
24th Hr.							
SETTLING VOLUME	(ml)						
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH		8.0	7.9	8.1	8.0	7.7	6.4
Paste							
1:5 H_2O							
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)	0.1	0.1	0.1	0.1	0.1	0.2
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage		49.9	35.6	30.9	36.3	44.1	65.9
EC_e @ 25°C	(mmhos/cm)	1.42	1.73	1.30	1.42	1.30	1.36
Ca^{++}	(me/l)	3.37	4.51	3.34	4.01	4.17	3.28
Mg^{++}	(me/l)	7.02	9.53	7.53	8.84	4.46	8.54
Na^{+}	(me/l)	5.72	6.20	4.28	3.44	3.08	2.72
K^{+}	(me/l)						
CO_3^{-}	(me/l)						
HCO_3^{-}	(me/l)						
Cl^{-}	(me/l)						
SO_4^{-}	(me/l)						
NO_3^{-}	(me/l)						
SAR	(me/l)	2.51	2.34	1.84	1.36	1.48	1.12
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	3.01	2.93	2.52	1.96	1.83	1.19
ACIDITY							
1N KCL exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	9.13	6.11	5.06	5.88	8.44	16.0
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 34
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

INTRASEARCH, INC. DRILL HOLE 24530-2C (cont'd)

Study Area: Cook Mountain, Mt
Location. Sec. 30 Twp. 2S. Range 45E.
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: Date:

DETERMINATION		DATA (mg/l)
Laboratory Number		27,415
Sack Number		
Depth		177.6-178.0
ALUMINUM	Al	
SILVER	Ag	
ARSENIC	As	
BORON	B	4.00
BARIUM	Ba	
BERYLLIUM	Be	
CADMIUM	Cd	0.19
COBALT	Co	
CHROMIUM	Cr	
COPPER	Cu	8.36
IRON	Fe	136.00
MERCURY	Hg	0.038
LITHIUM	Li	
MANGANESE	Mn	6.26
MOLYBDENUM	Mo	0.20
NICKEL	Ni	0.72
PHOSPHOROUS	P	
LEAD	Pb	56.00
STRONTIUM	Sr	
SELENIUM	Se	0.02
VANADIUM	V	
ZINC	Zn	12.6

LABORATORY DESCRIPTION		
DETERMINATION		DATA
Laboratory Number		27,415
Sack Number		
DEPTH	(ft)	177.6-178.0
PARTICLE SIZE ANALYSIS	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	
Coarse Sand	(1.0-0.5 mm)	
Medium Sand	(0.5-0.25 mm)	
Fine Sand	(0.25-0.10 mm)	
Very Fine Sand	(0.10-0.05 mm)	
TOTAL SAND	(2.0-0.05 mm)	21.6
SILT	(0.05-0.002 mm)	30.6
CLAY	(0.002 mm)	47.8
TEXTURAL CLASS (LAB)		C
BULK DENSITY	(g/cm^3)	
HYDRAULIC CONDUCTIVITY	(in/hr)	
6th Hr.		
24th Hr.		
SETTLING VOLUME	(ml)	
MOISTURE RETENTION	(percent)	
1/10 bar		
1/3 bar		
15 bar		
SOIL REACTION-pH		
Paste		6.9
1:5 H_2O		
1:2 0.01 M $CaCl_2$		
ORGANIC CARBON	(percent)	
AVAILABLE PHOSPHORUS	(ppm)	0.1
Ca CO_3 EQUIVALENT	(percent)	
GYPSUM REQUIREMENT	(me/100g)	
SATURATION EXTRACT		
Saturation Percentage		49.4
EC_e @ 25°C	(mmhos/cm)	1.11
Ca++	(me/l)	1.00
Mg++	(me/l)	0.71
Na+	(me/l)	20.70
K+	(me/l)	
CO_3-	(me/l)	
HCO_3-	(me/l)	
Cl-	(me/l)	
SO_4-	(me/l)	
NO_3-	(me/l)	
SAR	(me/l)	22.40
Na	(me/100g)	
Ca+Mg	(me/100g)	
1:5 EXTRACT		
EC_s @ 25°C	(mmhos/cm)	
Ca+Mg	(me/l)	
EXCHANGEABLE SODIUM	(percent)	14.9
ACIDITY		
1N KCL exchange acidity		
Total	(me/100g)	
Al+++	(me/100g)	
CATION EXCHANGE CAPACITY	(me/100g)	37.5
NaOAc@pH 8.2		
BORON	(mg/l)	

Table 34
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

INTRASEARCH, INC. DRILL HOLE 3458-3C

Study Area: Cook Mountain, Montana | Relief: | Stoniness: | Parent Material:

Location. Sec. 8 Twp. 3S. Range 45E. | Elevation: | | Soil Series:

| Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: | Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		27,473	27,474	27,475	27,476	27,477	27,478
Sack Number							
Depth		15.0-20.0	20.0-26.0	26.0-32.0	32.0-42.0	42.0-52.0	52.0-56.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.60	1.20	1.60	0.90	0.60	0.50
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.02	0.01	0.02	0.04	0.01
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.13	0.77	0.43	1.78	3.42	0.76
IRON	Fe	78.60	49.80	73.80	136.0	173.0	86.70
MERCURY	Hg	0.098	0.070	0.084	0.137	0.213	0.137
LITHIUM	Li						
MANGANESE	Mn	17.50	11.60	20.90	23.50	18.50	12.60
MOLYBDENUM	Mo	0.02	0.02	0.02	0.42	0.57	0.25
NICKEL	Ni	0.40	0.17	0.30	1.00	1.50	0.24
PHOSPHOROUS	P						
LEAD	Pb	10.20	10.10	2.10	4.60	4.00	1.60
STRONTIUM	Sr						
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02	0.02
VANADIUM	V						
ZINC	Zn	0.85	0.60	0.63	2.91	4.15	0.93

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		27,473	27,474	27,475	27,476	27,477	24,478
Sack Number							
DEPTH	(ft)	15.0-20.0	20.0-26.0	26.0-32.0	32.0-42.0	42.0-52.0	52.0-56.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	15.6	6.0	18.7	28.2	7.8	48.2
SILT	(0.05-0.002 mm)	52.9	42.4	62.4	40.2	46.0	38.3
CLAY	(0.002 mm)	31.5	51.6	18.9	31.6	46.2	13.5
TEXTURAL CLASS (LAB)		SiCL	SiC	SiL	CL	SiC	L
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.							
24th Hr.							
SETTLING VOLUME	(ml)						
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste		8.0	8.1	8.1	8.1	7.9	7.7
1:5 H_2O							
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)	0.1	0.1	0.1	0.2	0.1	0.1
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage		42.3	51.0	32.4	37.4	50.4	26.1
EC_e @ 25° C	(mmhos/cm)	2.77	0.78	0.81	1.02	1.55	1.55
Ca++	(me/l)	2.47	0.91	1.25	1.89	3.37	3.63
Mg++	(me/l)	7.21	1.38	1.68	3.75	8.21	5.65
Na+	(me/l)	20.90	5.24	5.24	5.00	5.96	8.80
K+	(me/l)						
CO_3-	(me/l)						
HCO_3-	(me/l)						
Cl-	(me/l)						
SO_4-	(me/l)						
NO_3-	(me/l)						
SAR	(me/l)	9.50	4.90	4.33	2.98	2.48	4.09
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25° C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	10.60	5.01	4.70	3.37	3.18	3.50
ACIDITY							
1N KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	12.30	9.83	6.81	8.10	8.80	6.58
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 35
Sheet 1 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
Intrasearch, Inc. Drill Hole 3458-3C (cont'd)

Study Area: Cook Mountain, Montana Relief: Stoniness: Parent Material:

Location. Sec. 8 Twp. 3S Range 45E Elevation: Soil Series:

Slope Aspect: Drainage: Soil Classification:

Climate: Vegetation: Ground Water:

Land Use: Erosion: Land Form: Profile Description By: Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		24,479	24,480	24,481	24,482	24,483	24,484
Sack Number							
Depth		56.0-66.0	66.0-76.0	76.0-79.0	79.0-83.5	85.0-89.0	89.0-93.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	2.10	0.80	1.00	1.20	1.20	1.00
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.05	0.04	0.03	0.03	0.03	0.03
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	3.19	2.76	2.40	3.02	2.66	1.16
IRON	Fe	170.00	148.00	153.00	166.00	165.00	114.00
MERCURY	Hg	0.059	0.105	0.099	0.105	0.182	0.043
LITHIUM	Li						
MANGANESE	Mn	26.70	23.70	13.20	14.10	12.60	6.35
MOLYBDENUM	Mo	0.50	0.28	0.40	0.42	0.45	0.20
NICKEL	Ni	1.48	0.94	1.01	0.86	0.71	1.45
PHOSPHOROUS	P						
LEAD	Pb	4.50	3.00	3.00	4.70	3.40	1.90
STRONTIUM	Sr						
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02	0.02
VANADIUM	V						
ZINC	Zn	4.24	3.26	3.56	3.25	3.08	1.74

DETERMINATION		LABORATORY DESCRIPTION DATA					
Laboratory Number		24,479	24,480	24,481	24,482	24,483	24,484
Sack Number							
DEPTH	(ft)	56.0-66.0,	66.0-76.0,	76.0-79.0,	79.0-83.5,	85.0-89.0	89.0-93.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	10.0	6.4	11.8	10.0	10.0	55.5
SILT	(0.05-0.002 mm)	52.9	56.5	60.7	58.9	53.5	36.5
CLAY	(0.002 mm)	37.1	37.1	27.5	31.1	36.5	8.0
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiL	SiCL	SiCL	SL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.							
24th Hr.							
SETTLING VOLUME	(ml)						
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar							
SOIL REACTION-pH							
Paste		6.5	7.8	8.1	8.1	8.1	7.9
1:5 H_2O							
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)	0.1	0.1	0.1	0.1	0.1	0.1
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)						
SATURATION EXTRACT							
Saturation Percentage		45.0	44.5	34.8	38.3	36.7	30.8
EC$_e$@ 25°C	(mmhos/cm)	4.22	2.33	1.64	1.76	1.51	1.95
Ca++	(me/l)	23.60	7.56	2.25	2.42	2.21	4.38
Mg++	(me/l)	28.50	11.30	5.55	6.08	5.04	6.32
Na+	(me/l)	10.10	9.58	9.84	10.60	10.40	10.40
K+	(me/l)						
CO_3-	(me/l)						
HCO_3-	(me/l)						
Cl-	(me/l)						
SO_4-	(me/l)						
NO_3-	(me/l)						
SAR	(me/l)	1.98	3.12	4.98	5.14	5.46	4.50
Na	(me/100g)						
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC$_e$ @ 25°C	(mmhos/cm)						
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	1.66	3.09	5.28	4.12	4.92	3.52
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	16.0	9.49	6.58	8.10	7.28	6.81
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 35
Sheet 2 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
INTRASEARCH, INC. DRILL HOLE 3458-3C (cont'd)

Study Area: Cook Mountain, Montana | Relief: | Stoniness: | Parent Material:
Location. Sec. 8 Twp. 3S. Range 45E. | Elevation: | | Soil Series:
| Slope Aspect: | Drainage: | Soil Classification:
Climate: | Vegetation: | Ground Water:
Land Use: | Erosion: | Land Form: | Profile Description By: Date:

DETERMINATION		DATA (mg/l)				
Laboratory Number		27,485	27,486	27,487	27,488	27,489
Sack Number						
Depth		99.0-109.0	112.9-119.0	119.0-129.0	129.0-139.0	139.0-149.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	1.00	1.20	0.80	0.50	0.40
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.03	0.02	0.03	0.02	0.02
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	2.03	1.98	1.64	1.28	0.89
IRON	Fe	159.00	149.00	120.00	111.00	75.50
MERCURY	Hg	0.065	0.084	0.122	0.108	0.072
LITHIUM	Li					
MANGANESE	Mn	13.20	8.85	5.27	6.37	3.70
MOLYBDENUM	Mo	0.41	0.20	0.27	0.20	0.22
NICKEL	Ni	1.13	0.90	0.64	0.72	0.50
PHOSPHOROUS	P					
LEAD	Pb	2.90	3.90	3.20	4.00	4.80
STRONTIUM	Sr					
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02
VANADIUM	V					
ZINC	Zn	2.81	3.10	5.46	3.16	1.95

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		27,485	27,486	27,487	27,488	27,489
Sack Number						
DEPTH	(ft)	99.0-109.0	112.9-119.0	119.0-129.0	129.0-139.0	139.0-149.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	20.9	30.0	57.3	36.9	51.5
SILT	(0.05-0.002 mm)	56.7	49.8	33.4	50.0	41.0
CLAY	(0.002 mm)	22.4	20.2	9.3	13.1	7.5
TEXTURAL CLASS (LAB)		SiL	L	SL	L	SL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.						
24th Hr.						
SETTLING VOLUME	(ml)					
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste		8.0	8.4	8.3	8.4	8.4
1:5 H_2O						
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)	0.1	0.1	0.1	0.1	0.1
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		34.9	30.1	28.7	30.6	29.7
EC_e @ 25° C	(mmhos/cm)	2.08	2.10	2.43	2.65	2.27
Ca^{++}	(me/l)	3.95	2.10	2.81	2.34	1.89
Mg^{++}	(me/l)	6.70	4.31	3.99	5.12	2.70
Na^{+}	(me/l)	13.60	15.50	19.10	24.20	23.00
K^{+}	(me/l)					
CO_3^{-}	(me/l)					
HCO_3^{-}	(me/l)					
Cl^{-}	(me/l)					
SO_4^{-}	(me/l)					
NO_3^{-}	(me/l)					
SAR	(me/l)	5.89	8.66	10.40	12.50	15.20
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25° C	(mmhos/cm)					
Ca+Mg	(me/l)					
EXCHANGEABLE SODIUM	(percent)	4.59	5.77	5.57	7.42	8.44
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	7.74	7.51	5.06	5.65	5.06
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 35
Sheet 3 of 4

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
INTRASEARCH, INC. DRILL HOLE 3458-3C (cont'd)

Study Area: Cook Mountain, Montana | Relief: | Stoniness: | Parent Material:

Location. Sec. 8 Twp. 3S. Range 45E. | Elevation: | | Soil Series:

| Slope Aspect: | Drainage: | Soil Classification:

Climate: | Vegetation: | Ground Water:

Land Use: | Erosion: | Land Form: | Profile Description By: Date:

DETERMINATION		DATA (mg/l)				
Laboratory Number		27,490	27,491	27,492	27,493	27,494
Sack Number						
Depth		149.0-159.0	160.0-169.0	177.8-179.8	179.8-185.0	241.8-243.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.80	0.60	0.40	1.50	0.80
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.02	0.04	0.07	0.24	0.10
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	1.66	2.30	3.10	2.94	5.40
IRON	Fe	193.00	162.00	189.00	298.00	149.00
MERCURY	Hg	0.099	0.177	0.143	0.093	0.143
LITHIUM	Li					
MANGANESE	Mn	11.00	17.50	58.70	25.40	14.00
MOLYBDENUM	Mo	0.25	0.25	0.23	0.20	0.35
NICKEL	Ni	0.53	0.45	1.64	6.76	1.64
PHOSPHOROUS	P					
LEAD	Pb	4.20	7.60	10.70	8.20	25.00
STRONTIUM	Sr					
SELENIUM	Se	0.02	0.02	0.02	0.02	0.02
VANADIUM	V					
ZINC	Zn	2.27	2.35	5.58	27.70	6.52

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		27,490	27,491	27,492	27,493	27,494
Sack Number						
DEPTH	(ft)	149.0-159.0	160.0-169.0	177.8-179.8	179.8-185.0	241.8-243.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	27.8	11.1	16.5	54.4	6.5
SILT	(0.05-0.002 mm)	51.1	52.0	37.7	29.1	43.9
CLAY	(0.002 mm)	21.1	36.9	45.8	16.5	49.6
TEXTURAL CLASS (LAB)		SiL	SiCL	C	SL	SiC
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.						
24th Hr.						
SETTLING VOLUME	(ml)					
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar						
SOIL REACTION-pH						
Paste		8.5	8.5	7.9	6.0	7.8
1:5 H_2O						
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)	0.1	0.1	0.1	0.1	0.1
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		32.1	37.9	40.6	42.7	40.6
EC_e @ 25°C	(mmhos/cm)	2.65	2.90	4.09	6.57	2.77
Ca++	(me/1)	1.44	1.24	3.03	21.00	1.98
Mg++	(me/1)	2.22	2.55	3.18	15.80	1.94
Na+	(me/1)	23.60	26.20	40.90	73.00	25.40
K+	(me/1)					
CO_3-	(me/1)					
HCO_3-	(me/1)					
Cl-	(me/1)					
SO_4-	(me/1)					
NO_3-	(me/1)					
SAR	(me/1)	17.50	19.0	23.2	17.0	18.1
Na	(me/100g)					
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)					
Ca+Mg	(me/1)					
EXCHANGEABLE SODIUM	(percent)	13.80	15.9	16.1	15.9	16.4
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	7.28	8.10	11.70	22.10	10.90
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 35
Sheet 4 of 4

RESULTS OF TRACE ELEMENT ANALYSES ON SAMPLES FROM USBR POINT SITE SOIL PROFILES - COOK MOUNTAIN STUDY AREA, MONTANA

Sample No.	Elements - Level (ppm)				
	B	Cd	Cu	Fe	Hg
V-1	0.50	0.08	3.40	22.60	0.045
V-2	0.34	0.06	2.00	20.40	0.043
V-3	0.00	0.08	2.60	14.80	0.053
V-4	0.00	0.02	6.20	12.40	0.055
V-5	0.00	0.02	3.40	10.60	0.035
V-6	1.00	0.12	3.00	17.60	0.030
V-7	0.41	0.10	5.40	14.20	0.030
V-8	0.34	0.06	4.60	14.60	0.033
V-9	0.34	0.04	4.80	17.80	0.025
V-10	0.07	0.00	6.40	19.20	0.028
V-11	1.25	0.06	3.60	15.20	0.039
V-12	0.23	0.08	3.60	15.00	0.029
V-13	0.57	0.06	3.60	15.20	0.032
V-14	0.00	0.12	2.80	38.40	0.024
V-15	0.00	0.06	3.60	33.80	0.021
V-16	0.00	0.06	2.80	21.80	0.024
V-17	0.00	0.00	1.80	9.80	0.018
V-18	0.00	0.00	2.20	8.60	0.018
V-19	0.00	0.00	1.60	9.80	0.029
V-20	0.00	0.00	1.80	12.00	0.027
V-21	0.07	0.00	2.00	11.40	0.035
V-22	0.50	0.00	2.80	12.20	0.035
V-23	0.36	0.08	2.20	23.60	0.029
V-24	0.34	0.06	2.00	20.40	0.029
V-25	0.23	0.06	2.00	11.00	0.032
V-26	0.09	0.02	1.80	8.00	0.032
V-27	0.27	0.02	2.00	5.00	0.027
V-28	0.23	0.00	2.00	8.40	0.027
V-29	1.13	0.04	5.40	10.40	0.035
V-30	2.17	0.06	6.00	13.00	0.064
V-31	3.67	0.06	10.40	41.40	0.056
V-32	0.16	0.06	1.40	29.60	0.032
V-33	0.00	0.04	2.00	33.60	0.034
V-34	0.00	0.04	2.20	26.40	0.037
V-35	0.00	0.04	1.60	19.80	0.037
V-36	0.00	0.02	2.00	11.80	0.039
V-37	0.00	0.00	2.20	9.00	0.045
V-38	0.00	0.00	0.60	5.60	0.026
V-39	0.34	0.10	1.20	28.00	0.024
V-40	0.02	0.08	1.40	14.60	0.029
V-41	0.00	0.02	1.60	8.00	0.026
V-42	0.02	0.02	1.80	8.20	0.024
V-43	0.41	0.02	1.00	9.40	0.018
V-44	0.70	0.02	1.20	10.00	0.021
V-45	0.45	0.02	1.00	12.40	0.021

RESULTS OF TRACE ELEMENT ANALYSES ON SAMPLES FROM USBR POINT SITE SOIL PROFILES - COOK MOUNTAIN STUDY AREA, MONTANA

Sample No.	Elements - Level (ppm)				
	Mn	Mo	Ni	Pb	Zn
V-1	41.00	0.18	1.40	1.00	2.52
V-2	27.80	0.09	1.80	0.80	1.50
V-3	15.80	0.07	1.40	0.80	1.12
V-4	13.60	0.09	0.80	0.60	3.76
V-5	11.20	0.02	0.60	0.60	2.08
V-6	41.40	0.15	1.20	1.00	2.60
V-7	38.20	0.04	1.20	1.40	3.66
V-8	25.60	0.09	1.00	1.40	2.40
V-9	20.60	0.11	0.80	1.20	2.48
V-10	16.20	0.09	0.60	1.00	3.28
V-11	15.80	0.07	0.60	1.20	1.52
V-12	14.40	0.07	0.60	1.20	1.72
V-13	14.80	0.07	0.60	1.20	2.02
V-14	51.80	0.00	1.00	0.80	2.60
V-15	48.40	0.04	1.80	0.80	1.70
V-16	25.80	0.00	1.60	0.80	1.06
V-17	9.60	0.02	0.60	0.60	0.70
V-18	8.60	0.11	0.40	0.60	0.94
V-19	6.80	0.09	0.20	0.60	0.64
V-20	6.80	0.13	0.20	0.60	0.74
V-21	9.00	0.37	0.40	0.60	0.98
V-22	9.80	0.26	0.20	0.60	1.70
V-23	39.00	0.02	1.40	0.80	1.46
V-24	34.60	0.00	1.60	0.60	0.82
V-25	18.00	0.13	1.00	0.80	0.86
V-26	11.00	0.00	0.60	0.60	0.74
V-27	10.60	0.00	0.40	0.60	1.10
V-28	8.80	0.18	0.20	0.80	0.76
V-29	9.40	0.11	0.40	2.00	1.14
V-30	4.40	0.16	0.40	2.60	1.98
V-31	1.80	0.36	0.20	1.00	2.50
V-32	29.60	0.00	0.40	1.00	1.56
V-33	34.60	0.07	0.60	0.60	2.10
V-34	21.60	0.00	0.60	0.80	1.42
V-35	21.00	0.00	0.60	0.80	0.84
V-36	9.60	0.11	0.40	0.60	1.92
V-37	7.60	0.07	0.40	0.60	1.48
V-38	3.00	0.00	0.20	0.40	0.42
V-39	38.00	0.00	0.80	0.80	2.54
V-40	37.00	0.09	1.00	1.00	0.68
V-41	12.60	0.09	0.60	0.40	0.56
V-42	11.80	0.00	0.60	0.80	0.60
V-43	12.20	0.27	0.20	0.60	0.38
V-44	14.60	0.29	0.40	0.80	0.52
V-45	11.40	0.25	0.20	0.80	2.50

Table 37

Criteria Used to Determine Suitability of Overburden Material
For Use as Plant Media in Revegetation 1/

Parameter	Methodology	Suitable	Limited Suitability	Unsuitable
Texture	Pipette method plus sand sieving	FSL, VFSL, L, SiL, SCL	LFS, SL, CL, SiCL, SC	S, LS, SiC, C
Electrical Conductivity (mmhos/cm)	Saturation extract/conductivity bridge	<4	4-12	>12
pH	Saturated paste/glass electrode	6.0 - 8.4	5.0 - 6.0; 8.4 - 9.0	<5.0; >9.0
Sodium Adsorption Ratio (SAR)	Calculate: $Na/\sqrt{(Ca + Mg)/2}$ Ca, Mg, and Na in meq/l	<6	6-9 heavy textures 6-12 medium and coarse textures	>9 - heavy textures >12 - medium and coarse textures
Exchangeable Sodium Percentage (ESP)	Ammonium acetate extraction; calculate: Na/CEC x 100%	<5	5-15	>15 2/
Boron (mg/l)	Hot water extraction/ carmine method	<5		>5
Selenium (mg/l)	Hydride generation; flameless AA	<2		>2
Molybdenum (mg/l)	Ammonium oxalate extraction; flameless AA or N_2O flame AA - 5000	<1		>1
Copper (mg/l)	DTPA extraction; AA	3/		3/
Manganese (mg/l)	DTPA extraction; AA	<60		>60
Zinc (mg/l)	DTPA extraction; AA	<40		>40
Lead (mg/l)	DTPA extraction; AA	10-15 (pH < 6) 15-20 (pH > 6)		15 (pH < 6) 20 (pH > 6)
Cadmium (mg/l)	DTPA extraction; AA	<1		>1
Nickel (mg/l)	DTPA extraction; AA	2-3		>3
Mercury (mg/l)	Extraction by H_2SO_4; flameless AA (quartz cell)	<0.5		>0.5
Iron (mg/l)	-		Not Established	
Nitrate-Nitrogen (mg/l)	-		Not Established	

1/ Applicable only to reclamation study areas in Montana and North Dakota.
2/ Rate 2:1 - Clay texture poor if >10, sand texture if >20.
3/ Suspect level not established - an excessive consumption of molybdenum through ingestation of vegetation may be toxic to animals. This concern is directly related to the Cu:Mo ratio in the plant tissue.

Suitability of Overburden Material For Use As Plant Media in Revegetation
Intrasearch, Inc. Drill Hole No. 24530-2C
Cook Mountain Study Area, Montana

Depth (Ft.)	Type	Suitability	Limiting Factors
15.0-24.8	CSist, Ss	Limited	% Sodium
25.0-33.5	CSist, Ss	Limited	% Sodium
35.0-44.5	Sh, Cbsh	Unsuitable	% Clay, Carbonaceous
45.0-53.9	Css	Suitable	--
55.0-65.0	Css	Suitable	--
65.0-75.0	Css	Limited	Texture
75.0-85.0	Css	Limited	Texture
85.2-95.0	Ssh, Sish	Suitable	--
95.0-105.0	Css	Suitable	--
105.0-113.9	Css	Suitable	--
115.6-117.3	Sh	No sample	--
118.1-125.0	Sh, Cbsh	Limited	Carbonaceous
125.0-127.4	Cbsh	Unsuitable	% Clay
177.6-178.0	Hard Sh	Unsuitable	% Clay, % Sodium, lead

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Suitability of Overburden Material For Use As Plant Media in Revegetation -
Intrasearch, Inc. Drill Hole No. 3458-3C
Cook Mountain Study Area, Montana

Depth (Ft.)	Type	Suitability	Limiting Factors
10.0-14.7	Topsoil/clay	No sample	--
15.0-20.0	Ss	Limited	% Sodium, Texture
20.0-26.0	Ss, Sh	Unsuitable	% Clay
26.0-32.0	Ss, Sh	Suitable	
32.0-42.0	Hard Sh	Limited	Texture, Hardness
42.0-52.0	Hard Sh	Unsuitable	% Clay, Hardness
52.0-56.0	Ss	Suitable	--
56.0-66.0	Css	Limited	Salt, Texture
66.0-76.0	Cbsh	Limited	Texture, Carbonaceous
76.0-79.0	Ss, Sh	Suitable	--
79.0-83.5	Ss, Sh	No sample	--
85.0-89.0	Ss, Sh	Limited	Texture
89.0-93.0	Ss, Sh	Limited	Texture
93.0-99.0	Ss	Limited	Texture
99.0-109.0	Css	Suitable	--
109.0-109.4	Hard Sh	No sample	(Hardness)

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material For Use As Plant Media in Revegetation -
Intrasearch, Inc. Drill Hole No. 3458-3C (cont'd.)
Cook Mountain Study Area, Montana

Depth (Ft.)	Type	Suitability	Limiting Factors
112.9-119.0	Ss, Sh	Limited	% Sodium
119.0-129.0	Ss, Sh	Limited	% Sodium, Texture
129.0-139.0	Ss, Css	Limited	% Sodium
139.0-149.0	Css	Limited	% Sodium, Texture
149.0-159.9	Css, Ss	Unsuitable	% Sodium
160.0-169.0	Ss, Sh	Unsuitable	% Sodium
169.0-177.6	Ss, Sh	No Sample	
177.8-179.8	Ss, Cbsh	Unsuitable	% Sodium, % Clay
179.8-185.0	Cbsh	Unsuitable	% Sodium, Nickel
241.8-243.0	Sh	Unsuitable	% Sodium, % Clay, lead

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
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Soil is characterized by laboratory methods to confirm judgement in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land catergorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is to be obtained. Problems should be studied rather than standard or routine tests made (Kellogg, 1962).

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In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail (Peters, 1965).

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability (Gardner, 1945) through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride

in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio (Richards, 1954).

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase 1 of the scheme, all samples would be characterized for (1) soil structure stability thorugh measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, selected samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, selected samples suspected through the testing results of Phase 1 and 11 to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase 1 to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.ON potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases 1, 11, and 1V to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Soils and Water Laboratory Procedures and References

I. Soil Characterization

A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvements of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).

2. Settling Volume, Imoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).

3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).

4. Particle Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).

5. Bulk Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).

6. Moisture Retention is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

7. Field Capacity - field determination.

8. Water holding capacity - determined by calculation: field capacity-wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with automated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater; Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical Analysis of Soils, 1964), and (Brown,

Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979, EPA-600 4-79-020, 365.1:365.1-1-365.1-9).

3. Nitrate-Nitrite are determined by phenoldsulfonic acid and by Automated cadmium reduction (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971, Thirteenth Edition, 133:233-237), (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7).

4. Sulfate is determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 375.2:375.2-1-375.2-4), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition, 156C: 334-336).

5. Sodium, Potassium, Calcium and Magnesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

C. Trace Metals

1. Trace Metals are determined by atomic absorption with flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 50-157), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition), and (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600-4-79-020).

D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook

No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical Analysis of Soils, 1964).

2. pH reading in $CaCl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

3. Saturation Extract taken from saturated soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical Analysis of Soils, 1964).

4. Exchangeable Sodium and Potassium are extracted by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 72-3:1033, 72-3.2.1:1034 and 57-1:891-895).

5. Exchangeable Sodium Percentage is determined by calculation relationship being $\frac{Na}{CEC} \times 100$ (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).

6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).

7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).

8. Boron was determined by extraction with hot water (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).

9. Percent Organic Carbon is determined with Technicon Auto Analyzer II.

10. Total Carbonate expressed as % calcium carbonate, acid-neutralization, (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 23c:105-106).

11. SAR (sodium adsorption ratio) determined by calculation: $SAR = \sqrt{(Ca + Mg)/2}$

GLOSSARY

Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Annual Plant (annuals) - A plant that completes its life cycle and dies in 1 year or less.

Aspect - The direction toward which a slope faces. Exposure.

Available Nutrient - The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock - Any consolidated material (shale, sandstone, etc.) soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer - Substances in soil or water that act chemically to resist changes in reaction of pH.

Calcareous Soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water - The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of the water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) - (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Colluvium - A general term applied to loose, heterogeneous (mixed) deposits of soil material and/or rock fragments near the base of rather steep slopes. The deposits have accumulated through mass wasting (slides), soil creep, and local wash.

Compaction - The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop - (See Nurse Crop).

Conifer - A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour - An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant - A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous - Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling - Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage - The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand - Density of stocking expressed in number of trees per acre.

Dissolved Solids - The difference between the total and suspended solids in water.

Disturbed Land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer - Tractor with a steel plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology - The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem - A total organic community in a defined area or time frame.

Effective Precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent - Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment - All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility - The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition) - A chemical element required for the normal growth of plants.

Evapotranspiration - A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation - The act of removing overburden material.

Fertilizer - Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade - The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer [nitrogen (N), phosphorous (P), and potassium (K)].

Fill - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage - Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land - Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minumum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on the farms are commonly called woodland or farm forests.

Germination - Sprouting; beginning of growth.

Gradation - A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size - Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

Ground Water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below water table. Also called plerotic water; phreatic water.

Growing Season - Determined by the Lowery-Johnson Method.

Gully Erosion - Removal of soil by running water with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding - Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Prohibits fluid flow.

Infiltration - The downward entry of water into the land surface.

Intermittent Stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences signigicant to men.

Land Use Planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching - The removal of materials in solution by the passage of water through soil.

Leachate - Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume - A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime - From strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or cabonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural

lime are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined), CaO
Hydrated Line - quicklime + H_2O $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate - A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients - Nutrients in only small, trace, or minute amounts.

Mined-Land - Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation - Natural reestablishment of plants; propragation of new plants over an area by natural processes.

Natural seeding (Volunteer) - Natural distribution of seed over an area.

Neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil - A soil in which the surface layer, at least from normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation - The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop - A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives away to the permanent crop. Sometimes referred to as a companion crop.

Nutrients - Any element taken into a plant that is essential to its growth.

Overburden - Barren rock material, usually unconsolidated, overlying a mineral deposit and which must be removed prior to mining.

Percolation - Downward movement of water through soils.

Permeability - The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH - The symbol or term refers to a scale commonly used to express the dees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of H+ activity).

Pollution - Environmental degradation resulting from man's activities or natural events.

Pond - A body of water of limited size either naturally or artificially cofined and usually smaller than a lake.

Rain - (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land - The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate - Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, ans has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation - The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile - The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land - Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation - The natural or artificial restocking of an area with forest trees.

Regrading - The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation - The reestablishment of a vegetative cover following land disturbance.

Ripping - The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted spoils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff - That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil - A soil having a combination of a harmful quantity of soluble salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil - A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation - Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin - A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and growth of seedlings.

Seep - A more or less poorly defined area where water oozes from the earth in small quantities.

Shale - Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt - Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil) - Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Amendment - Any substance used to alter one or more of the many soil properties. These include soil conditioning agents, fertilizers, lime and manures, to name a few.

Soil Conserving Crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity - The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Solum - The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in natural soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil - The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile) - Area created by the deposited soil or overburden material prior to backfilling. Also called cast overburden.

Stratified - Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip - To mine a deposit by first taking off the overlying burden.

Stripping - The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil - The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum - Alluvial, colluvial, or bedrock material that underlies the soil profile.

Surface Mining - Refers to a procedure of mining which entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as "strip mining."

Surface Soil - The upper part of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 minches) in non-arable soils.

Suspended Soilids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace - Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope - A slope that is intersected by one or more terraces.

Texture (Soils) - Refers to the fineness or coarseness of a soil. Specifically, it refers to the relative proportions of the various soil separates (sand, silt, clay) in a given soil.

Topdressing Material - Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil) - Includes acid spoil with pH below 4.0. Also refers to spoil containing excessive levels of exhangeable sodium or trace elements (i.e., selenium, lead, etc.).

Transpiration - The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material) - Soil material in a form of loose aggregation.

Vegetation - General term including grasses, legumes, shrubs, and trees naturally occurring and planted intentionally.

Vegetative Cover - The entire vegetative canopy on an area.

Volunteer - Springing up spontaneously or without being planted; a volunteer plant.

Weathering - The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife - Undomesticated vertebrate animals, except fish, considered collectively.

APPENDIX E
GREENHOUSE

Figure 1

Samples T1-T37

DRY WEIGHT FOR SOIL #1

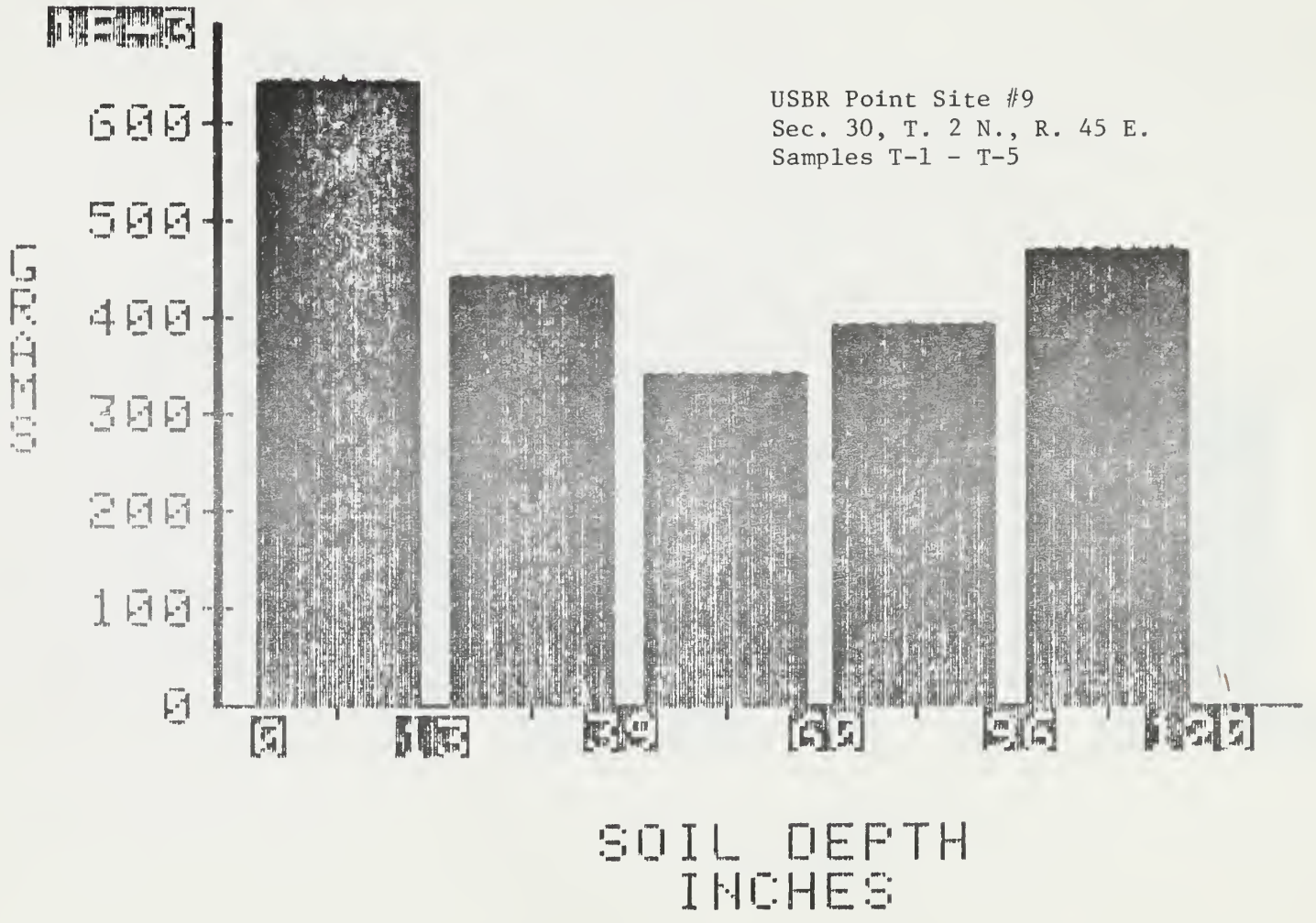


Figure 2

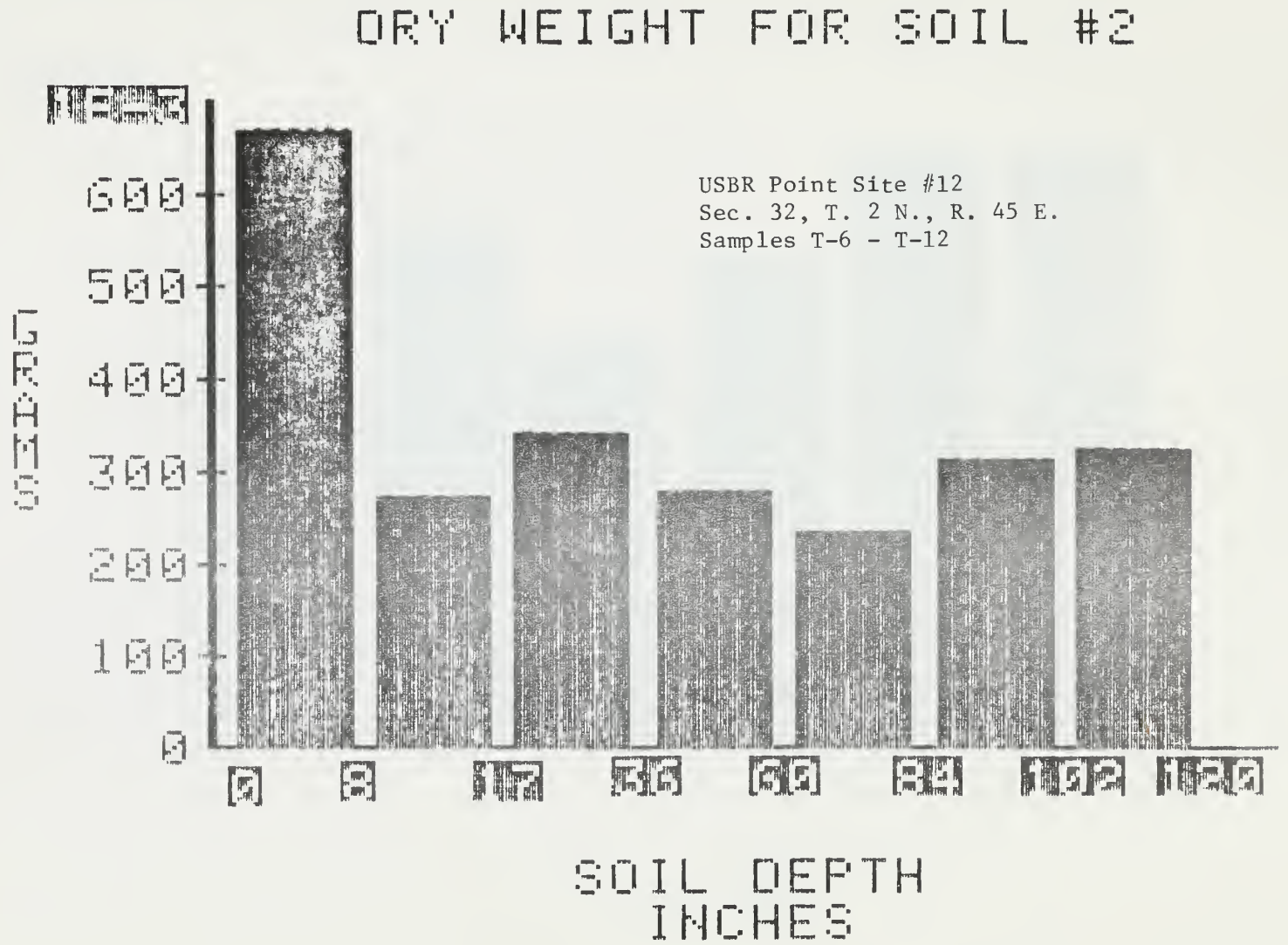

DRY WEIGHT FOR SOIL #2
USBR Point Site #12
Sec. 32, T. 2 N., R. 45 E.
Samples T-6 - T-12
600
500
400
300
200
100
0
SOIL DEPTH
INCHES

Figure 3

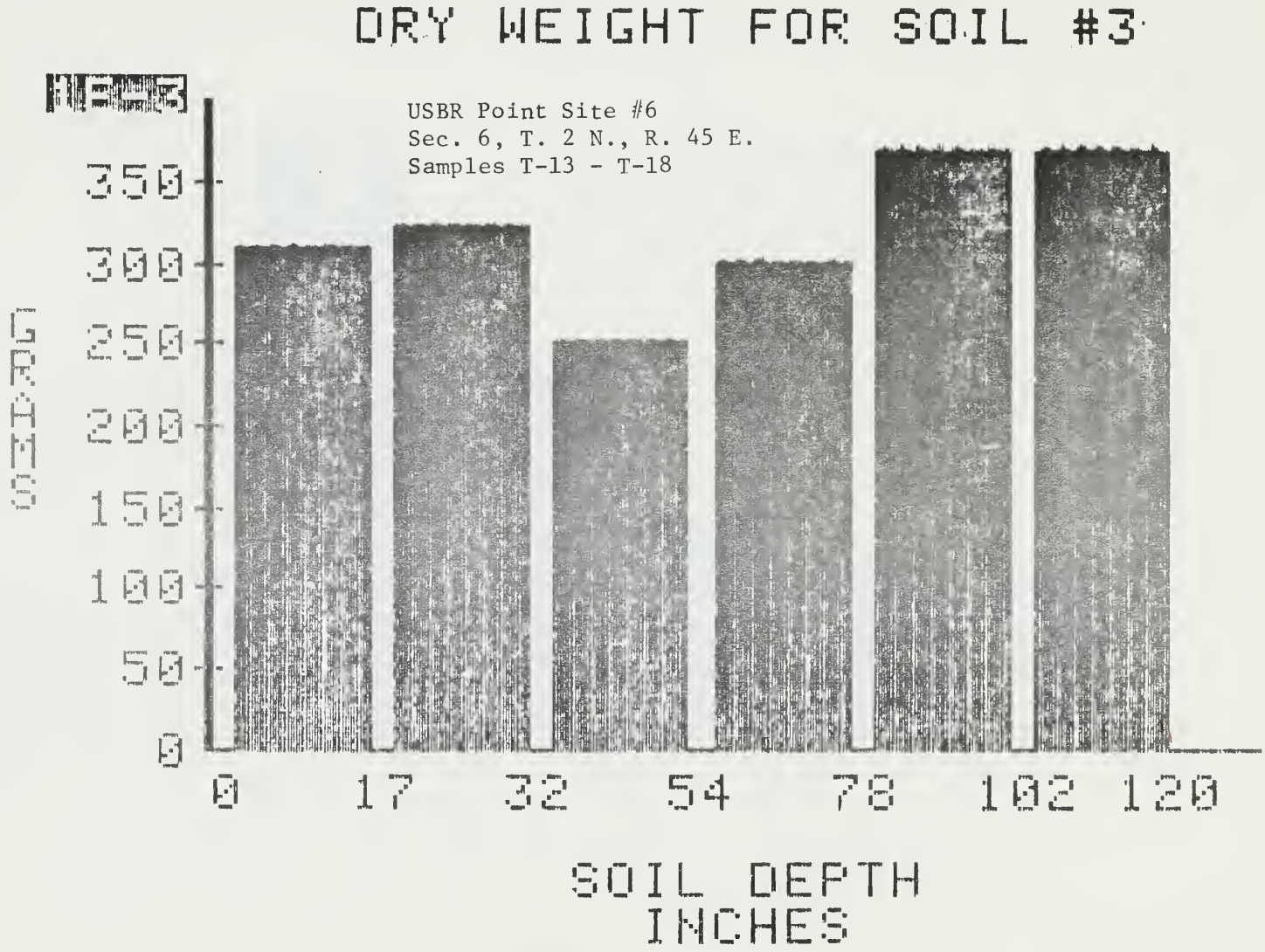

DRY WEIGHT FOR SOIL #3
USBR Point Site #6
Sec. 6, T. 2 N., R. 45 E.
Samples T-13 - T-18
0
50
100
150
200
250
300
350
0
17
32
54
78
102
120
SOIL DEPTH
INCHES

Figure 4

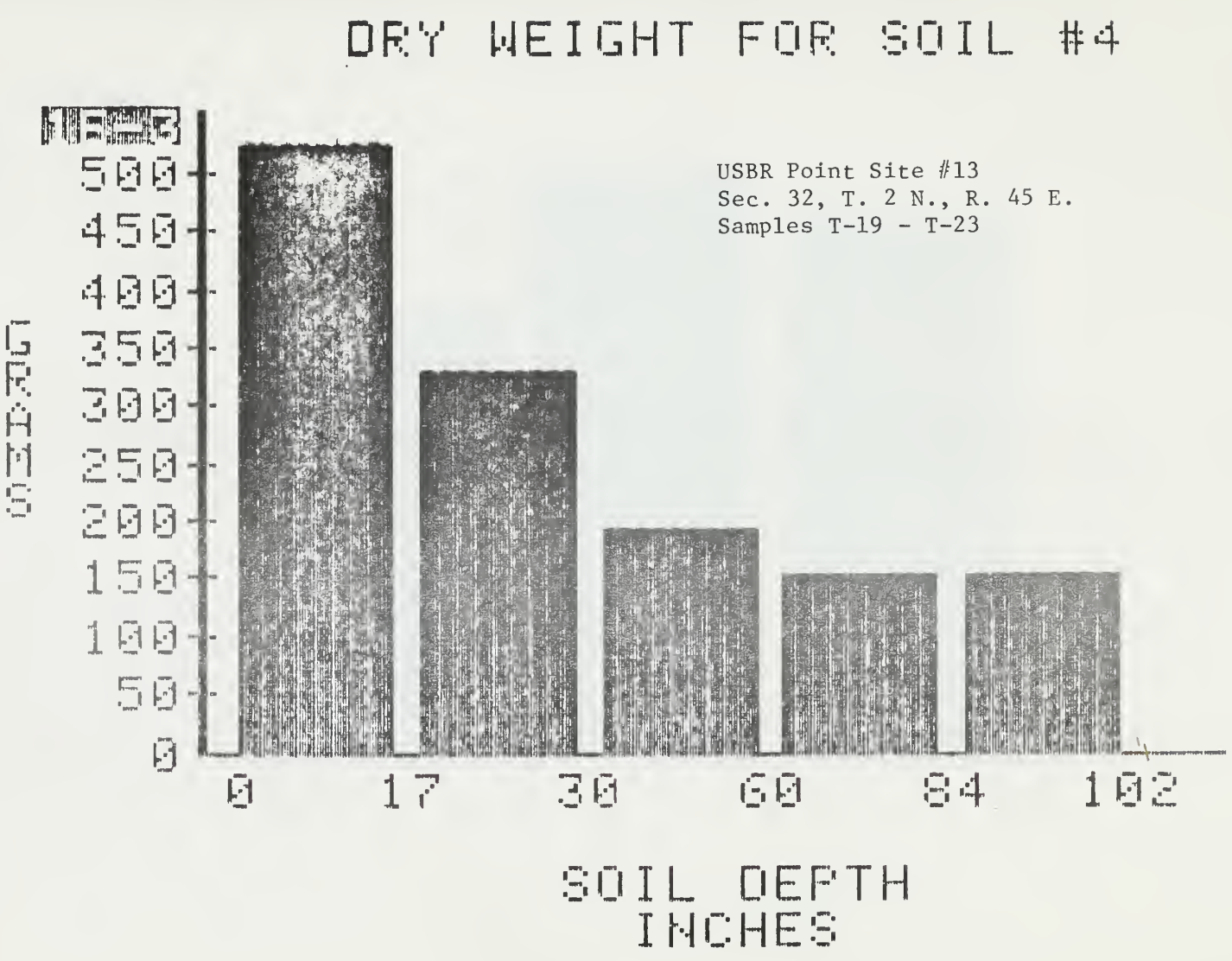

DRY WEIGHT FOR SOIL #4
USBR Point Site #13
Sec. 32, T. 2 N., R. 45 E.
Samples T-19 - T-23
0
17
30
60
84
102
SOIL DEPTH
INCHES

Figure 5

USBR Point Site #10
Sec. 30, T. 2 N., R. 45 E.
Samples T-24 - T-26

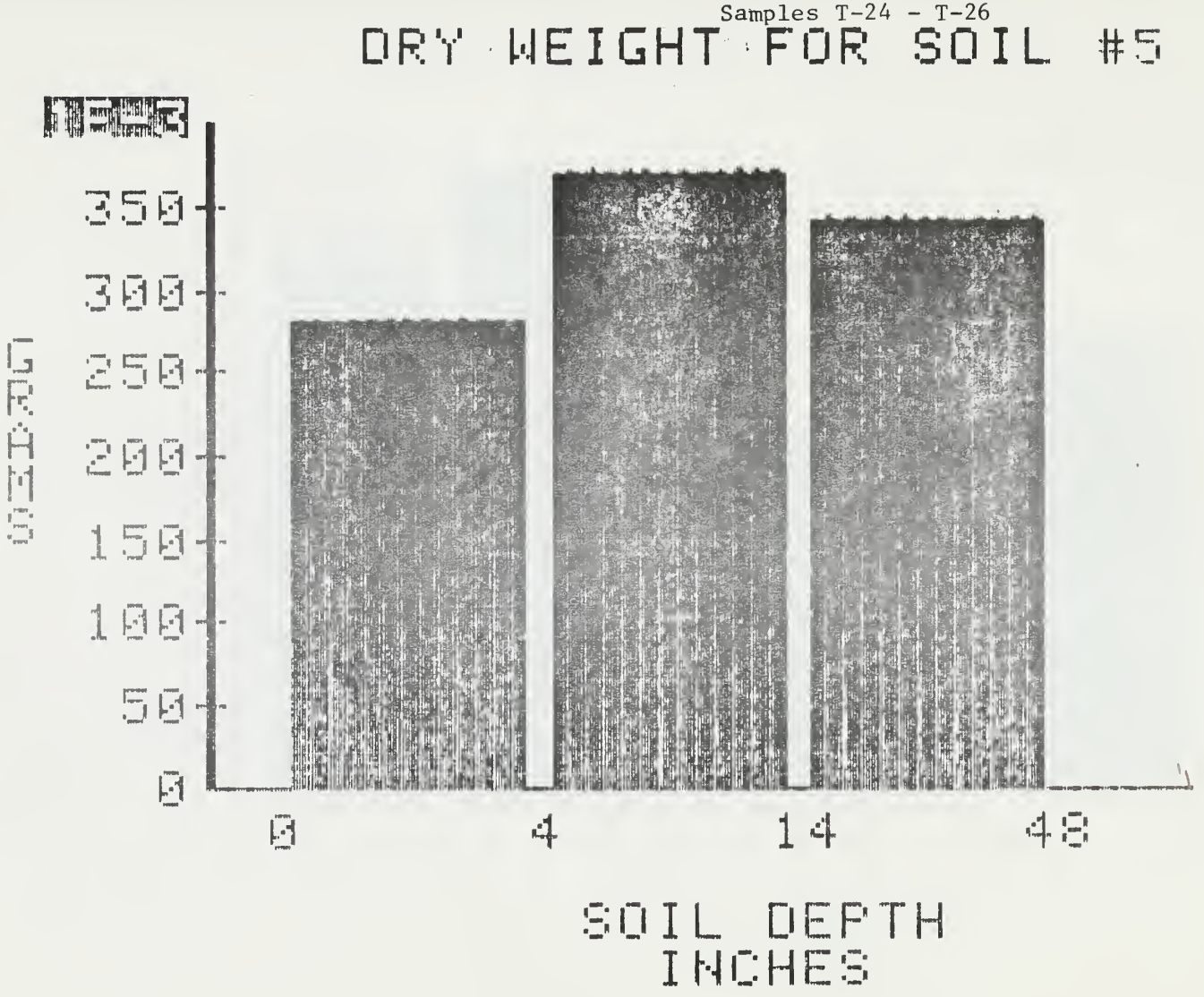


Figure 6

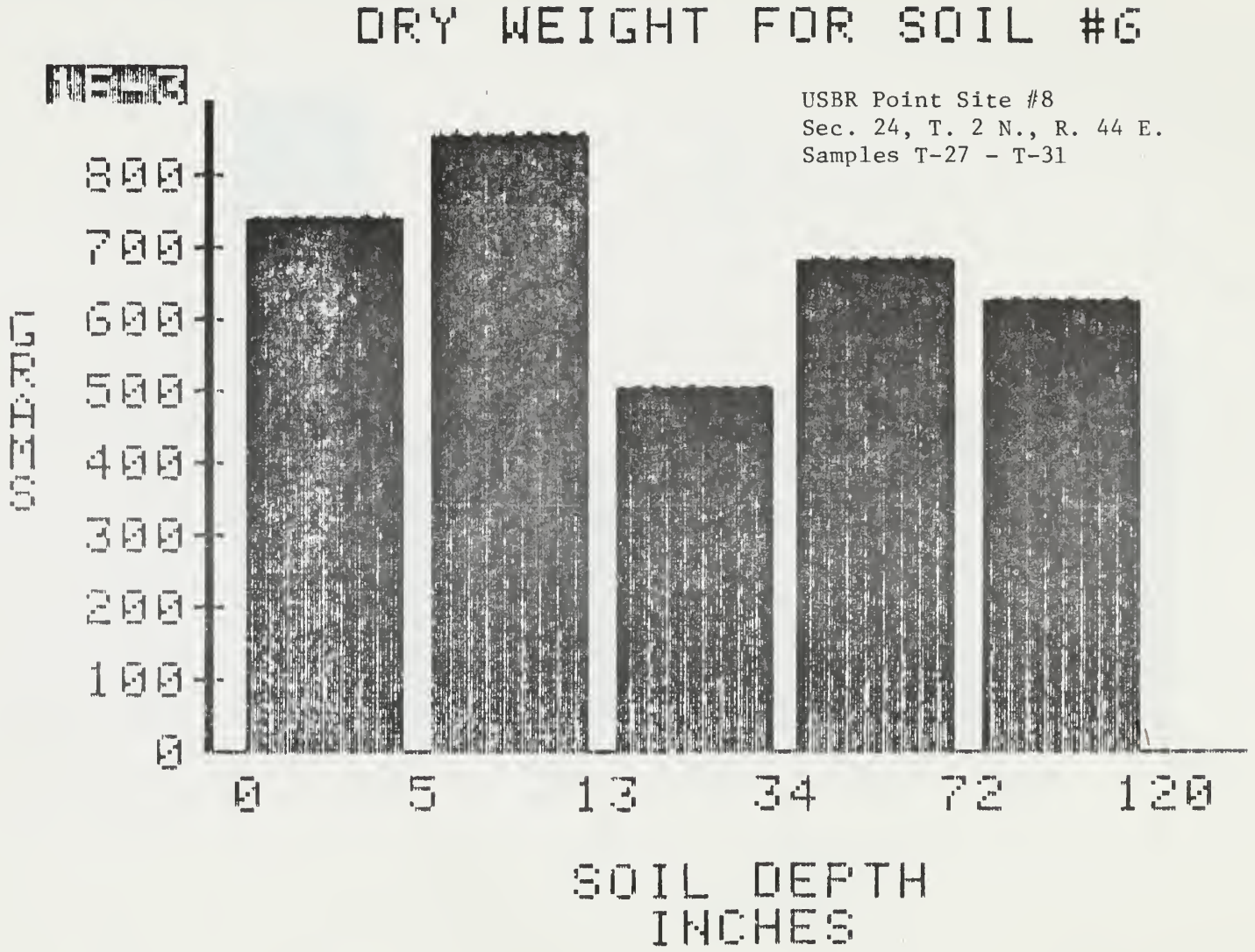

DRY WEIGHT FOR SOIL #6
USBR Point Site #8
Sec. 24, T. 2 N., R. 44 E.
Samples T-27 - T-31
GRAMS
0
100
200
300
400
500
600
700
800
0
5
13
34
72
120
SOIL DEPTH
INCHES

Figure 7

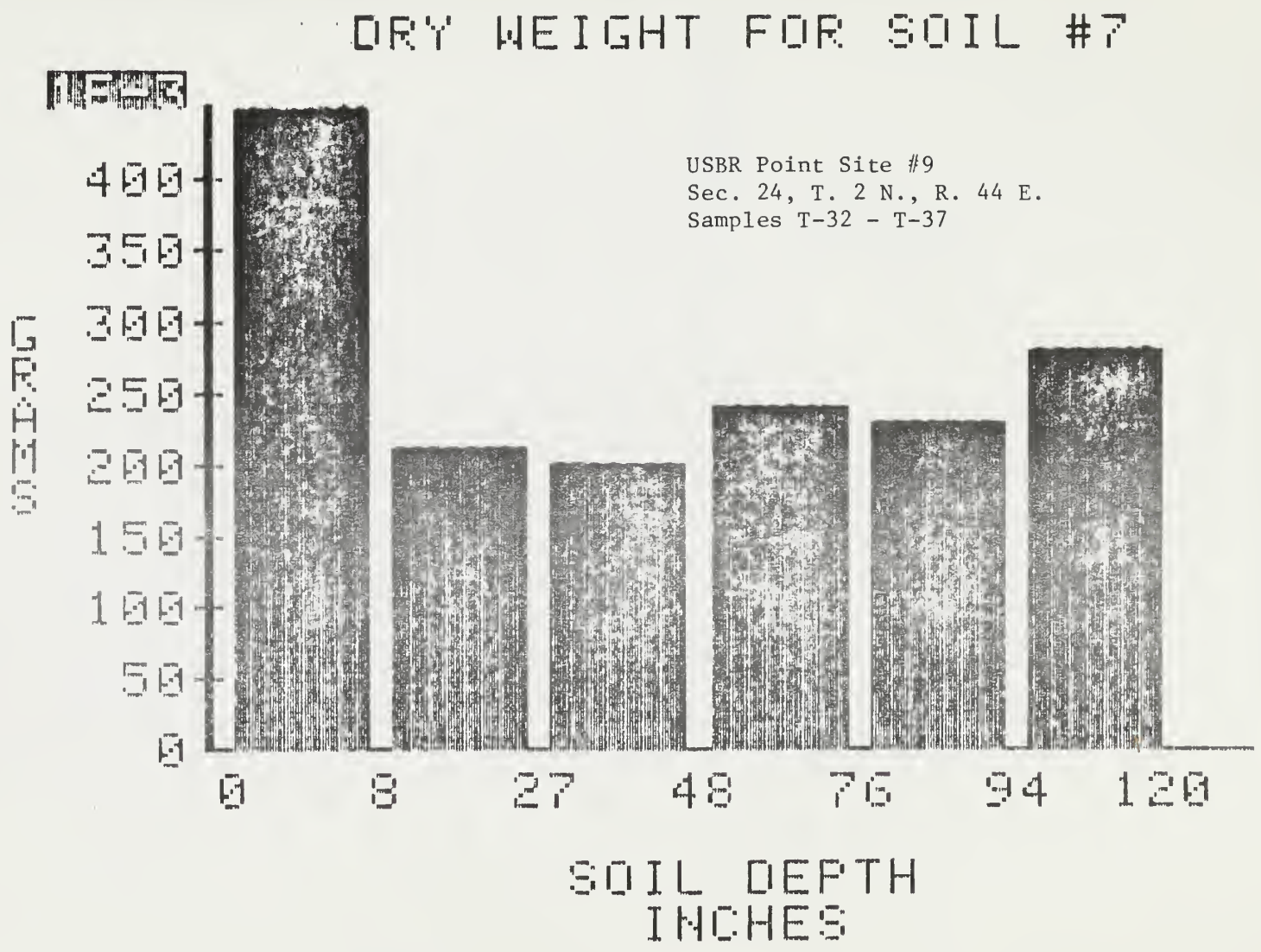

DRY WEIGHT FOR SOIL #7
USBR Point Site #9
Sec. 24, T. 2 N., R. 44 E.
Samples T-32 - T-37
WEIGHT
400
350
300
250
200
150
100
50
0
0
8
27
48
76
94
120
SOIL DEPTH
INCHES

Figure 8

Table 41

Analysis of Variance of Fresh and Dry Weights as Related to Soils.

"F" Test - ANOVA

Soil	T-No.	Fresh Weight	Dry Weight
1	1-5	1.41 NS	2.12 NS
2	6-12	4.70 *	4.05 *
3	13-18	0.02 NS	0.20 NS
4	19-23	13.56 **	8.76 **
5	24-26	0.76 NS	1.11 NS
6	27-31	0.71 NS	0.56 NS
7	32-37	6.41 **	2.55 NS
Total		1.88 **	0.46 NS

* Significant @ 0.05 level
** Significant @ 0.01 level

Test of Significance of Means of Dry Weight vs. Soil Horizons

Soil Number							
1		2		3		4	
Hor.	Mean	Hor.	Mean	Hor.	Mean	Hor.	Mean
T1	0.64	T6	0.67a	T13	0.31a	T19	0.52
T2	0.44ab	T7	0.27b	T14	0.32a	T20	0.33b
T3	0.34b	T8	0.34b	T15	0.25a	T21	0.19c
T4	0.39b	T9	0.28b	T16	0.30	T22	0.15c
T5	0.47ab	T10	0.23b	T17	0.37a	T23	0.15c
		T11	0.31b	T18	0.37		
		T12	0.32b				

Values followed by different letters are significantly different at the 0.05 level.

Test of Significance of Means of Dry Weight vs. Soil Horizons.(continued)

Soil Number					
5		6		7	
Hor.	Mean	Hor.	Mean	Hor.	Mean
T24	0.28a	T27	0.74a	T32	0.45a
T25	0.37a	T28	0.85a	T33	0.21b
T26	0.34a	T29	0.50a	T34	0.20b
		T30	0.68a	T35	0.24b
		T31	0.62a	T36	0.23b
				T37	0.28b

Values followed by different letters are significantly different at the 0.05 level.

Test of Significance of Means of Fresh Weight vs. Soil Horizons

Soil Number							
1		2		3		4	
Hor.	Mean	Hor.	Mean	Hor.	Mean	Hor.	Mean
T1	4.18a	T6	4.42a	T13	1.37a	T19	3.43a
T2	2.94b	T7	1.71b	T14	2.19a	T20	2.04b
T3	2.54b	T8	1.82b	T15	1.71a	T21	0.89c
T4	2.44b	T9	1.65b	T16	1.86a	T22	0.75c
T5	3.24ab	T10	1.09b	T17	2.58a	T23	0.77c
		T11	1.42b	T18	2.59a		
		T12	1.66b				

Values followed by different letters are significantly different at the 0.05 level.

Test of Significance of Means of Fresh Weight vs. Soil Horizons.(continued)

Soil Number					
5		6		7	
Hor.	Mean	Hor.	Mean	Hor.	Mean
T24	1.2a	T27	5.09a	T32	2.98a
T25	1.6a	T28	5.15a	T33	0.95b
T26	2.0a	T29	3.50a	T34	1.25b
		T30	4.80a	T35	1.43b
		T31	3.65a	T36	1.40b
				T37	1.46b

Values followed by different letters are significantly different at the 0.05 level.

Descriptive Condition of Plants on August 13,1981

Sample No.	Description
T-1	Fair germination; slight leaf yellowing; upright; all reps.
T-2	Good germination; slight tip burn; all reps.
T-3	Good germination; good color; 2 of 3 reps.
T-4	Fair germination; severe yellowing; all reps.
T-5	Good to fair germination; moderate yellowing; all reps.
T-6	Fair germination; severe yellowing; all reps.
T-7	Excellent germination; good color; all reps.
T-8	Excellent germination; good color; all reps.
T-9	Good germination; good color; all reps.
T-10	Good germination; good color; all reps.
T-11	Good germination; good color; two reps.
T-12	Excellent germination; good growth all reps.
T-13	Good germination; fair growth; moderate yellowing; all reps.
T-14	Good germination; good growth; all reps.
T-15	Good germination; good growth; all reps.
T-16	Good germination and growth in two reps. poor in third.
T-17	Good to fair germination; moderate to severe yellowing; all reps.
T-18	Good germination; fair growth; moderate leaf yellowing;

Descriptive Condition of plants on August 13, 1981

Sample No.	Description
T-19	Fair to poor germination; fair growth; moderate leaf yellowing;
T-20	Good germination; good growth in two reps, fair in third.
T-21	Good germination and good growth in two reps. poor in third.
T-22	Good germination; good growth; good color.
T-23	Good germination; good growth; good color.
T-24	Good germination; good growth; good color.
T-25	Good germination in two reps; good growth; slight tip burn.
T-26	Poor germination in two reps; fair growth; good color.
T-27	Good germination; good growth;
T-28	Fair germination; good growth; slight yellowing;
T-29	Fair germination; poor growth; severe yellowing;
T-30	Fair germination; poor growth; severe yellowing;
T-31	Fair germination; poor growth; moderate yellowing;
T-32	Fair germination; fair growth;
T-33	Good germination; fair to good growth;
T-34	Good germination in two reps, poor in third, good growth;
T-35	Poor germination; poor growth;
T-36	Poor germination; poor growth;
T-37	Good germination in two reps, poor in third; fair growth;

Top/Root Ratio for Selected Soils

Sample No.	Soil Depth	Top Weight	Root Weight	Top/Root Ratio
T-13	0-17	7.47	8.55	0.87
T-18	102-120	1.48	1.95	0.76
T-19	0-17	6.05	13.41	0.45
T-22	60.84	4.25	13.20	0.32
T-24	0-4	6.36	7.62	0.83
T-25	4-14	8.82	8.01	1.10
T-27	0-5	10.25	15.25	0.67
T-31	72-120	8.95	4.75	1.88
T-32	0-8	10.11	9.53	1.06
T-33	8-27	4.50	8.81	0.51
Control	-	14.78	9.52	1.55

Correlation Coefficients for Preplant Analysis

Dry Weights vs.	Correlation Coefficient (R)	Coefficient of Determination (R^2)
SAR	-0.547 **	0.299
EC	-0.424 **	0.179
Sat %	-0.276 **	0.076
pH	-0.523 **	0.274
Sand %	+0.598 **	0.358
Silt %	-0.470 **	0.221
Clay %	-0.516 **	0.266
CEC	+0.070 NS	0.005
As	-0.072 NS	0.005
B	-0.604 **	0.365
Mn	-0.411 **	0.169
Avail.K	+0.217 NS	0.047
Fe	-0.162 NS	0.026
Zn	0	0
Cu	0	0
P	0	0
Mo	0	0
Sat.Ext.Ca	-0.155 NS	0.024
Sat.Ext.Mg	-0.164 NS	0.027

** Statistically significant at 0.01%.

Plant Tissue Analysis

Sample No.	P %	K %	Ca %	Mg %
T-1	0.51	3.68	.80	.36
T-2	0.48	2.77	.53	.58
T-3	0.63	2.65	.24	.81
T-4	0.63	2.96	.24	.86
T-5	0.62	2.81	.24	.69
T-6	0.51	3.38	.69	.40
T-7	0.35	1.44	.18	.39
T-8	0.31	1.84	.20	.40
T-9	0.35	1.81	.24	.38
T-10	0.31	2.39	.52	.41
T-11	0.38	2.50	.34	.37
T-12	0.27	2.33	.29	.33
T-13	0.50	3.67	.76	.47
T-14	0.39	2.13	.43	.56
T-15	0.51	2.31	.28	.68
T-16	0.41	2.14	.21	.66
T-17	0.59	2.32	.17	.53
T-18	0.54	2.21	.18	.62
T-19	0.41	3.51	.83	.40
T-20	0.32	1.85	.39	.37
T-21	0.28	2.78	.31	.66
T-22	0.25	2.42	.14	.54
T-23	0.31	2.63	.16	.52
T-24	0.37	3.66	.45	.50
T-25	0.43	3.91	.38	.56
T-26	0.34	3.37	.29	.51
T-27	0.45	3.29	.79	.29
T-28	0.49	2.43	.67	.27
T-29	0.60	3.11	.70	.33
T-30	0.82	3.90	.81	.57
T-31	0.55	2.62	.31	.64
T-32	0.56	4.11	.69	.37
T-33	0.24	2.34	.28	.37
T-34	0.27	2.55	.17	.44
T-35	0.33	2.76	.12	.43
T-36	0.36	2.51	.12	.42
T-37	0.30	2.05	.12	.36

Plant Tissue Analysis (continued)

Sample No.	Zn ppm	B ppm	Mn ppm	Mo ppm
T-1	166.1	3.0	34.2	<0
T-2	90.1	7.6	42.6	<0
T-3	20.9	4.8	41.1	<0
T-4	18.9	8.0	45.1	1.7
T-5	33.5	11.9	50.2	3.6
T-6	24.8	5.1	47.5	.2
T-7	32.6	8.1	54.3	1.5
T-8	30.9	15.2	57.9	1.6
T-9	12.8	23.3	69.6	3.4
T-10	14.8	53.6	90.7	6.4
T-11	25.6	83.2	75.4	3.2
T-12	38.0	67.0	78.6	5.2
T-13	12.1	5.8	56.2	0.9
T-14	20.8	8.5	46.5	<0
T-15	22.8	6.8	47.4	0.8
T-16	31.1	8.9	48.0	0.8
T-17	28.9	16.2	55.9	4.5
T-18	22.0	36.3	36.3	6.6
T-19	22.8	5.8	44.3	0.6
T-20	18.4	4.55	41.2	<0
T-21	14.2	12.1	68.8	1.5
T-22	5.7	30.3	70.0	3.6
T-23	5.4	36.2	83.6	5.9
T-24	42.5	13.3	21.8	1.6
T-25	49.9	47.8	11.0	1.6
T-26	28.2	34.2	36.8	2.1
T-27	12.3	3.1	24.7	<0
T-28	13.1	1.4	18.7	0.4
T-29	48.2	4.1	35.1	0.8
T-30	62.4	4.6	52.5	1.5
T-31	45.8	3.1	29.9	0.8
T-32	22.7	3.0	40.7	<0
T-33	18.9	12.3	71.1	1.4
T-34	12.4	39.0	61.6	3.8
T-35	22.3	31.2	76.5	3.8
T-36	32.1	22.0	57.9	3.2
T-37	20.4	17.3	43.6	3.2

Plant Tissue Analysis (continued)

Sample No.	Cu ppm	Fe ppm	Cd ppm	Pb ppm	As ppm
T-1	<0	147.9	<0	1.1	<0
T-2	<0	113.5	<0	<0	<0
T-3	<0	86.3	<0	<0	2.3
T-4	<0	285.2	<0	<0	3.5
T-5	<0	157.7	<0	<0	0.7
T-6	<0	82.8	<0	<0	0.6
T-7	<0	110.0	<0	<0	5.9
T-8	<0	106.3	<0	<0	0.8
T-9	<0	107.6	<0	<0	3.9
T-10	<0	143.0	<0	<0	<0
T-11	<0	121.6	<0	<0	.1
T-12	<0	2258.5	<0	<0	1.9
T-13	<0	165.2	<0	<0	<0
T-14	<0	119.9	<0	<0	<0
T-15	<0	170.9	<0	<0	4.4
T-16	<0	248.7	<0	<0	.8
T-17	<0	161.3	<0	<0	.3
T-18	<0	128.5	<0	<0	.2
T-19	<0	109.0	<0	<0	1.5
T-20	<0	172.7	<0	<0	<0
T-21	<0	201.7	<0	<0	1.3
T-22	<0	99.2	<0	<0	<0
T-23	<0	113.7	<0	<0	<0
T-24	<0	68.6	<0	0.8	1.9
T-25	<0	86.1	<0	<0	1.6
T-26	<0	167.4	<0	<0	3.8
T-27	<0	72.8	<0	<0	<0
T-28	<0	97.6	<0	<0	<0
T-29	<0	162.7	<0	<0	2.2
T-30	<0	116.1	<0	<0	<0
T-31	<0	71.4	<0	<0	<0
T-32	<0	109.1	<0	<0	0.4
T-33	<0	82.7	<0	<0	1.9
T-34	<0	203.5	<0	<0	<0
T-35	<0	113.9	<0	<0	<0
T-36	<0	117.9	<0	<0	<0
T-37	<0	88.6	<0	<0	.2

Comparisons of Plant Tissue Analysis with Other Data

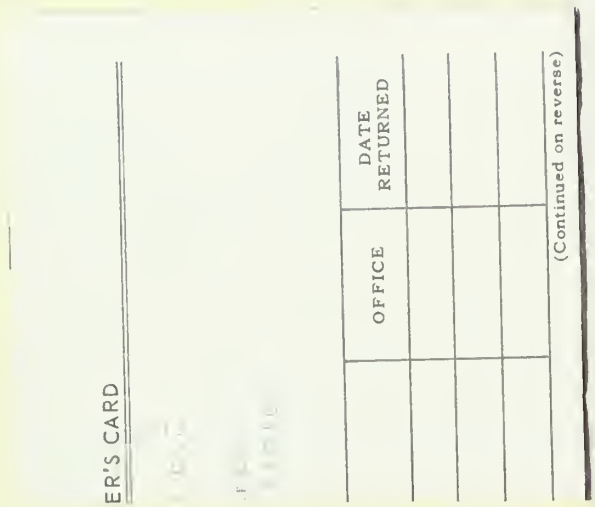
Plant Nutrient	Mean of 37 Samples	Bauer's Data*	
P%	0.43	0.41	0.05
K%	2.74	0.51	2.39
Ca%	0.39	0.05	0.28
Mg%	0.49	0.19	0.16
Zn ppm	30.93	48	12
Al ppm	114.64	90	173
B ppm	18.88	3	44
Mn ppm	50.46	69	62
Pb ppm	0.08	NA	NA
As ppm	1.09	NA	NA
Mo ppm	2.05	11	11
Fe ppm	188.37	138	397
Cu ppm	0	2	11

* Data for wheat; First number for grain and second number for straw. Bauer et.al 1976 Physical, Chemical and Biological Aspects of Strip-Mined Lands in Western North Dakota.Final Report to Old West Regional Comm. Nov. 1976, 605 p.

Correlation Coefficients for Plant Tissue Analysis

Dry Weight Vs.	Correlation Coefficient (R)	Coefficient of Determination (R^2)
P%	0.557 **	0.310
K%	0.294 NS	0.086
Ca%	0.621 **	0.386
Mg%	-0.174 NS	0.030
Na ppm	-0.370 *	0.137
Zn ppm	0.305 NS	0.093
B ppm	-0.370 *	0.137
Mn ppm	-0.425 **	0.181
Pb ppm	0.244 NS	0.060
As ppm	-0.278 NS	0.077
Mo ppm	-0.435 **	0.189
Fe ppm	-0.128 NS	0.016
Al ppm	-0.185 NS	0.034
Cu ppm	ND	ND
Cd ppm	ND	ND

ND = not detected.



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